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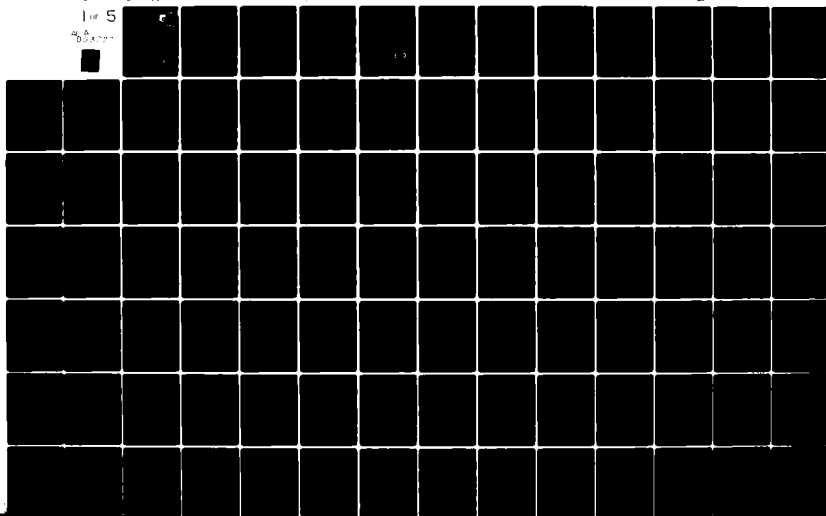
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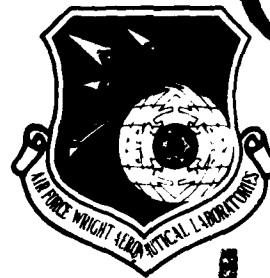
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ELASTIC PROPERTIES OF T300/5208 BIDIRECTIONAL SYMMETRIC LAMINATES

SOM R. SONI

*MECHANICS & SURFACE INTERACTIONS BRANCH
NONMETALLIC MATERIALS DIVISION*

SEPTEMBER 1980

TECHNICAL REPORT AFWAL-TR-80-4111

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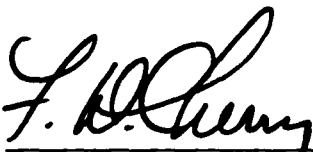


SOM R. SONI, Project Engineer
Mechanics & Surface Interactions Br.
Nonmetallic Materials Division



S. W. TSAI, Chief
Mechanics & Surface Interactions Br.
Nonmetallic Materials Division

FOR THE COMMANDER



F. D. CHERRY, Chief
Nonmetallic Materials Division

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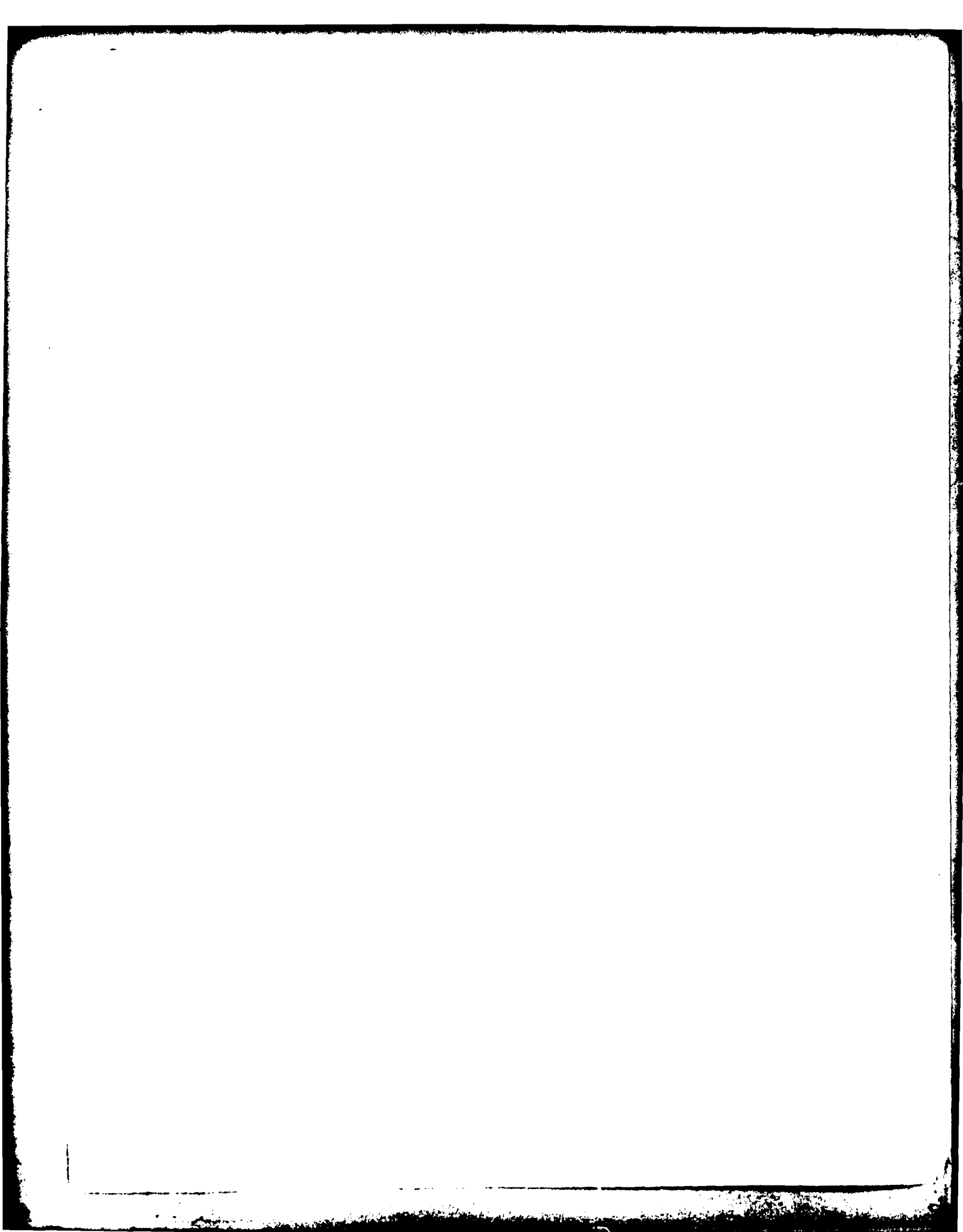
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FOREWORD

This report describes the inhouse effort conducted in the Mechanics and Surface Interactions Branch (MLBM), Nonmetallic Materials Division (MLB), Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio, under the National Research Council-Air Force Systems Command research associateship program.

The work reported herein was performed during the period 1 September 1979 to 1 July 1980. Dr. Stephen W. Tsai (AFWAL/MLBM) was the Project Engineer and Dr. S. R. Soni was the NRC-AFSC Senior Postdoctorate Research Associate.

The author wishes to express his deep sense of gratitude to Dr. S. W. Tsai for his extremely fruitful guidance in the course of this work. Figures I - III and Tables 1 - 13 have been taken from the book, "Introduction to Composite Materials," by S. W. Tsai and H. T. Hahn with their permission.

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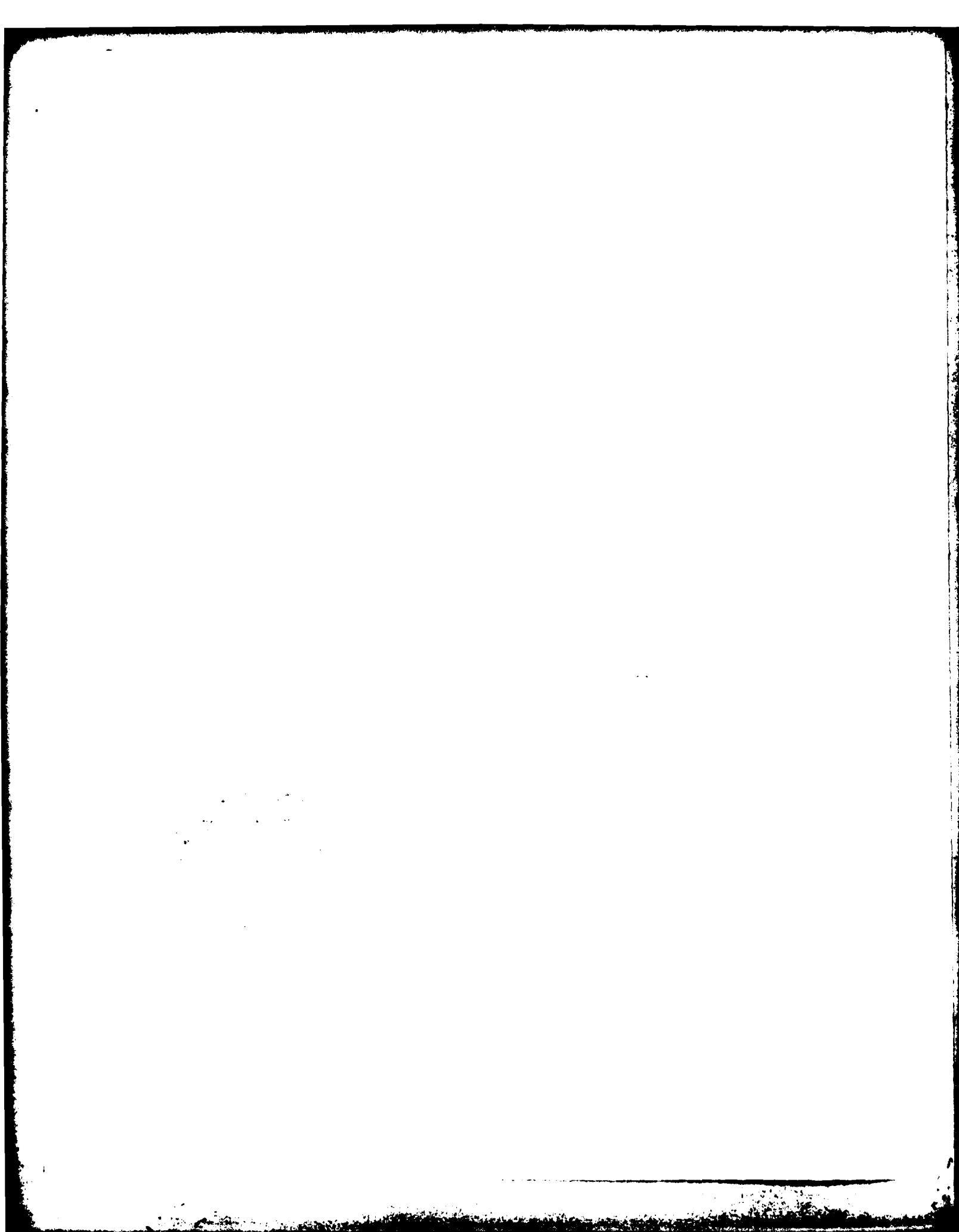


TABLE OF CONTENTS

SECTION		PAGE
I	INTRODUCTION	1
II	STIFFNESS PROPERTIES	4
	1. Unidirectional Laminate Stress Strain Relations	4
	2. Transformation of Stress and Strain	6
	3. Off-Axis Modulus	8
	4. Inplane Stiffness of Symmetric Laminates	10
III	RESULTS	16
	1. Stiffness	16
	2. Strength	17
	3. Illustrations	18
IV	CONCLUSIONS	19
	REFERENCES	20

LIST OF ILLUSTRATIONS

FIGURE		PAGE
I	Angle Notations in an Angle Ply Laminate ($-\phi_{n_1}/\phi_{n_2}$) _s Rotated by an Angle γ	2
II	Off-Axis Configuration of a Unidirectional Composite	7
III	Determination of Off-Axis Modulus	8
IV	Transverse Young's Modulus E_2^0 Versus Ply Angle ϕ of the Laminate for Various Volume Fractions	24
V	Compliance Component h_{11} Versus Rotation for Various Volume Fractions	25
VI	Longitudinal Poisson's Ratio for Bidirectional Laminates	26
1-16	Component A_{11} of Modulus Matrix for Different Bidirectional Laminates	28-43
17-32	Component A_{22} of Modulus Matrix for Different Bidirectional Laminates	44-59
33-48	Component A_{12} of Modulus Matrix for Different Bidirectional Laminates	60-75
49-64	Component A_{66} of Modulus Matrix for Different Bidirectional Laminates	76-91
65-80	Component A_{16} of Modulus Matrix for Different Bidirectional Laminates	92-107
81-96	Component A_{26} of Modulus Matrix for Different Bidirectional Laminates	108-123
97-112	Component a_{11} of Compliance Matrix for Different Bidirectional Laminates	126-141
113-128	Component a_{22} of Compliance Matrix for Different Bidirectional Laminates	142-157
129-144	Component a_{12} of Compliance Matrix for Different Bidirectional Laminates	158-173
145-160	Component a_{66} of Compliance Matrix for Different Bidirectional Laminates	174-189

LIST OF ILLUSTRATIONS
(Concluded)

FIGURE		PAGE
161-176	Component a_{16} of Compliance Matrix for Different Bidirectional Laminates	190-205
177-192	Component a_{26} of Compliance Matrix for Different Bidirectional Laminates	206-221
193-208	Longitudinal Poisson's Ratio ν_{11}^0 for Various Bidirectional Laminates	224-239
209-224	Longitudinal Shear Coupling Ratio ν_{12}^0 for Various Bidirectional Laminates	240-255
225-240	Transverse Poisson's Ratio ν_{12}^0 for Various Bidirectional Laminates	256-271
241-256	Transverse Shear Coupling Ratio ν_{21}^0 for Various Bidirectional Laminates	272-287
257-272	Longitudinal Normal Coupling Ratio ν_{16}^0 for Various Bidirectional Laminates	288-303
273-288	Transverse Normal Coupling Ratio ν_{26}^0 for Various Bidirectional Laminates	304-319
289-304	Longitudinal Young's Modulus E_1^0 for Various Bidirectional Laminates	322-337
305-320	Transverse Young's Modulus E_2^0 for Various Bidirectional Laminates	338-353
321-336	Longitudinal Shear Modulus E_6^0 for Various Bidirectional Laminates	354-369
337-352	Moduli Ratio E_1^0/E_2^0 for Various Bidirectional Laminates	370-385
353-368	Moduli Ratio E_1^0/E_6^0 for Various Bidirectional Laminates	386-401
369-384	Moduli Ratio E_2^0/E_6^0 for Various Bidirectional Laminates	402-417
385-414	Strengths of Different Laminates for Various Loading Patterns	420-449

LIST OF TABLES

TABLE		PAGE
1	Various Parameters Considered for Computation of Results in $(-\phi_{n_1}/\phi_{n_2})$ Laminates and Rotation γ	3
2	On-Axis Stress Strain Relations-Compliance	4
3	On-Axis Stress Strain Relations-Modulus	4
4	Stress Transformation Relations	6
5	Strain Transformation Relations	6
6	Off-Axis Stress Strain Relations	9
7	Modulus Components Q_{ij}	9
8	Stress Strain Relations-Modulus	10
9	Stress Strain Relations-Compliance	11
10	Modulus Components, A_{ij}	12
11	Stress Strain Relations-Modulus	13
12	Stress Strain Relations-Compliance	13
13	Stress Strain Relations-Engineering Constants	14
14	Point Loading Patterns Considered	17
15	Material Properties of T300/5208	21
16	Values of Transverse Young's Modulus E_2 for Different Volume Fractions of Bidirectional Laminates as Obtained from Figure IV	22
17	Values of Compliance Component h_{11} for Different Volume Fractions of Bidirectional Laminates as Obtained from Figure V.	23

NOMENCLATURE

a	=	Young's moduli ratio E_1^0/E_2^0
A_{ij}	=	In-plane modulus of multidirectional laminates, in Pam.
a_{ij}	=	In-plane compliance of multidirectional laminates, it is the inverse of A_{ij} , in (Pam) ⁻¹
b	=	Young's moduli ratio E_1^0/E_6^0
c	=	Young's moduli ratio E_2^0/E_6^0
E_x, E_y	=	Longitudinal, transverse Young's modulus for a ply
E_1^0, E_2^0	=	Longitudinal, transverse Young's modulus for a laminate
E_s	=	Longitudinal shear modulus for a ply
E_6^0	=	Longitudinal shear modulus for a laminate
h	=	Thickness of the laminate
m	=	$[1 - \nu_{xy}\nu_{yx}]^{-1}$ in relations (1)
	=	$\cos\theta$ in Tables (4) and (5)
N	=	Applied stress component causing failure of the laminate
N_i	=	Stress resultant, in Pam; $i=1,2,6$
n	=	$\sin\theta$
n_i	=	Number of plies of the i th ply assembly; $i=1,2,\dots,k$
Q_{ij}	=	On-axis modulus components ($i,j = x,y,s$)
	=	Off-axis modulus components ($i,j = j,2,6$)
S_{ij}	=	On-axis compliance components ($i,j = x,y,s$)

NOMENCLATURE (Continued)

U_i	=	Linear combination of modulus for the multiple angle transformation; $i = 1, 2, \dots, 5$
V_i^*	=	Integrals of trigonometric functions for the evaluation of in-plane modulus; $i = 1, 2, 3, 4$
x, y	=	Cartesian coordinate axes
$l, 2$	=	New or transformed coordinate axes
σ_i	=	Stress components on-axis; $i = x, y, s$
	=	Stress components off-axis; $i = 1, 2, 6$
$\bar{\sigma}_i$	=	N_i/h , average stress across thickness of a laminate; $i = 1, 2, 6$
ϵ_i	=	Strain components on-axis; $i = x, y, s$
	=	Strain components off-axis; $i = 1, 2, 6$
ϵ_i°	=	In-plane strain components for laminates; $i = 1, 2, 6$
ϕ	=	Counterclockwise angle as referred to angle ply
γ	=	Counterclockwise rigid body rotation of a laminate
θ	=	Angle of ply orientation; counterclockwise rotation is positive
ν_{xy}	=	Major Poisson's ratio
ν_{yx}	=	Minor Poisson's ratio
ν_{ij}°	=	In-plane coupling ratios, $i \neq j$; $i, j = 1, 2, 6$ ($\nu_{21}^\circ, \nu_{12}^\circ$ Poisson's ratios; $\nu_{61}^\circ, \nu_{62}^\circ$ shear coupling ratios; $\nu_{16}^\circ, \nu_{26}^\circ$ normal coupling ratios.

SUBSCRIPTS

- 1,2,6 = Represents directionality of material properties in multidirection laminates. [1: longitudinal; 2: transverse; 6: shear]
- x,y,s = Represents directionality of material properties in on-axis lamina [x: longitudinal; y: transverse; s: shear]
- ()_s = Symmetric about the midplane
- n_i = Number of plies in the ith ply assembly

SUPERSCRIPTS

- ° = Represents mid-plane properties for a laminate
- = In-plane strain components

SECTION I

INTRODUCTION

With the increasing demand for suitable materials with specific properties, it has been made clear that the naturally occurring materials cannot fulfill all the requirements. The introduction of alloying techniques have gone a long way toward satisfying these requirements but even that is not sufficient. The invention of fiber reinforced composites has been a great step forward in the quest for lightweight and strong materials. Carbon fiber composites have been characterized as stronger than steel yet lighter than aluminum. Researchers have been exploring the avenues for the best use of composites.

We have seen unique properties of laminates that do not have a counterpart in conventional materials. For example, the in-plane Poisson's ratio, shown in Fig. VI, extends beyond the upper limit of .5 imposed on isotropic materials. While orthotropic materials can be viewed as a simple extension of conventional materials, non-orthotropic materials, however, must be viewed from a completely different perspective. We must understand the unique properties of anisotropic materials and learn to capitalize on these properties to perform functions not possible with conventional materials. To the best of the author's knowledge, there exists no document that gives stiffness and strength properties of symmetric bidirectional laminates. The present report provides the engineering constants, modulus components, compliance components and strengths of T300/5208

bidirectional laminates. These properties are presented in graphical form as functions of either the angle ply ϕ for specific rotation γ or the rotation γ for specific laminate angle ply ϕ . The laminates considered were $(-\phi_{n1}/\phi_{n2})_s$.

The angles ϕ and γ rotations are given in Fig. I.

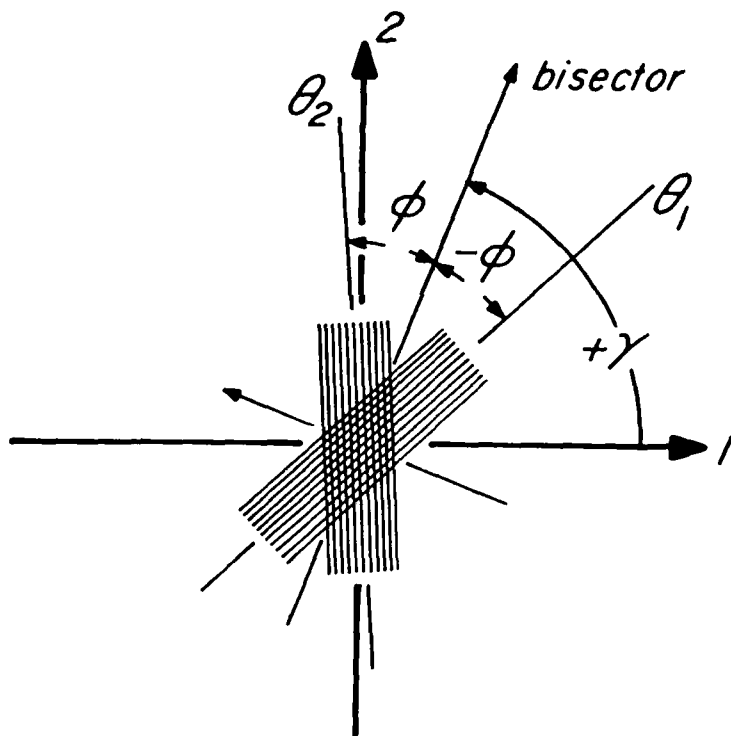


Fig. I. Angle notations in an angle ply laminate $(-\phi_{n1}/\phi_{n2})_s$ rotated by an angle γ .

For computation of results, the laminates given in Table 1 were considered:

Table 1. Various parameters considered for computation of results in $(-\phi_{n_1}/\phi_{n_2})_s$ laminates and rotation γ .

$-90^\circ < \phi < 90^\circ$ γ	n_1	n_2	$-90^\circ < \gamma < 90^\circ$ ϕ
-75	1	0	15
-60			30
-45	9	1	45
-30			60
-15	4	1	75
0			
15	1	1	
30			
45	1	4	
60	1	9	
75	0	1	

SECTION II

STIFFNESS PROPERTIES

1. UNIDIRECTIONAL LAMINATE STRESS STRAIN RELATIONS

The stiffness of unidirectional composites can be defined by appropriate stress strain relations. These relations can be expressed in terms of engineering constants, compliance components or modulus components. A detailed treatise on mechanics of composites is given in Reference 1. For completeness, the relevant relations are given in the present report. All the notations used in Reference 1 are followed in this work.

The two key stress strain relations for a unidirectional composite are, Tables 2 and 3:

Table 2: On axis stress strain relations - compliance

	σ_x	σ_y	σ_s
ϵ_x	S_{xx}	S_{xy}	
ϵ_y	S_{yx}	S_{yy}	
ϵ_s			S_{ss}

Table 3: On axis stress strain relations - modulus

	ϵ_x	ϵ_y	ϵ_s
σ_x	Q_{xx}	Q_{xy}	
σ_y	Q_{yx}	Q_{yy}	
σ_s			Q_{ss}

In the foregoing matrix multiplication table, each value in the first column is equal to the sum of products of corresponding

row elements with their column headings. This rule should be self evident.

$$\begin{aligned}
 \{\sigma_x, \sigma_y, \sigma_s\} &= \{\text{Longitudinal, transverse, shear}\} \\
 &\quad \text{stress components} \\
 \{\epsilon_x, \epsilon_y, \epsilon_s\} &= \{\text{Longitudinal, transverse, shear}\} \\
 &\quad \text{strain components} \\
 Q_{ij} &= \text{Modulus components} \\
 S_{ij} &= \text{Compliance components} \\
 S_{xx} &= 1/E_x \\
 S_{yy} &= 1/E_y \\
 S_{xy} &= -\nu_{xy}/E_y \\
 S_{yx} &= -\nu_{yx}/E_x \\
 S_{ss} &= 1/E_s \\
 Q_{xx} &= mE_x \\
 Q_{yy} &= mE_y \\
 Q_{xy} &= mE_x \nu_{xy} \\
 Q_{yx} &= mE_y \nu_{yx} \\
 Q_{ss} &= E_s \\
 m &= 1/(1-\nu_{yx}\nu_{xy})
 \end{aligned} \tag{1}$$

where

$$\begin{aligned}
 E_x &= \text{Longitudinal Young's modulus} \\
 E_y &= \text{Transverse Young's modulus} \\
 \nu_{yx} &= \text{Longitudinal Poisson's ration} = -\frac{\epsilon_y}{\epsilon_x} \\
 \nu_{xy} &= \text{Transverse Poisson's ratio} = -\frac{\epsilon_x}{\epsilon_y} \\
 E_s &= \text{Longitudinal shear modulus} = \frac{\sigma_s}{\epsilon_s}
 \end{aligned}$$

All the material constants of the stress strain relation shown above are called engineering constants. They are the familiar

constants used for conventional materials with subscript added to denote directionality of properties. Thus the use of engineering constants will often facilitate the use of composites for structural applications. But, it has been found more convenient to use compliance and modulus components of multidirectional composites. In Eq. (1) S_{ij} are compliance components and Q_{ij} are modulus components.

2. TRANSFORMATION OF STRESS AND STRAIN

The change of stiffness of unidirectional composites as a function of ply orientation is a unique feature of composites. These orientational variations of stress and strain are the fundamental underlying issues which must be understood. The relations governing these variations are called transformation equations and are given in Tables 4 and 5:

Table 4: Stress transformation relations

	σ_1	σ_2	σ_6
σ_x	m^2	n^2	$2mn$
σ_y	n^2	m^2	$-2mn$
σ_s	$-mn$	mn	$m^2 - n^2$

$$m = \cos \theta, \quad n = \sin \theta$$

Table 5: Strain transformation relations

	ϵ_1	ϵ_2	ϵ_6
ϵ_x	m^2	n^2	mn
ϵ_y	n^2	m^2	$-mn$
ϵ_s	$-2mn$	$2mn$	$m^2 - n^2$

Where $\sigma_1, \sigma_2, \sigma_6$ are off-axis stress components, $\sigma_x, \sigma_y, \sigma_s$ are transformed on-axis stress components and θ is the angle of counter clockwise rotation of the on-axis laminate (Fig. II).

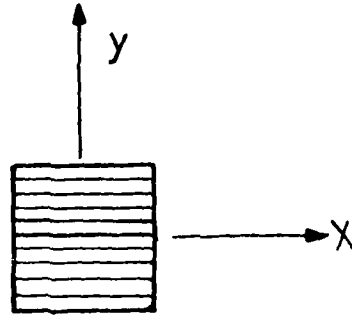


Fig. II(a): Material symmetry axis of a unidirectional composite.

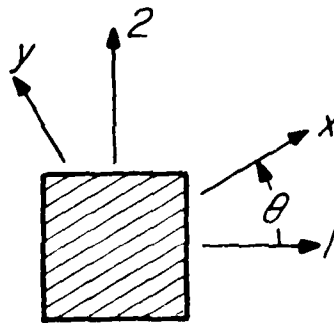


Fig. II(b): Off-axis configuration of a unidirectional composite, counter clockwise rotation is positive.

Similarly $\epsilon_1, \epsilon_2, \epsilon_6$ are off-axis and $\epsilon_x, \epsilon_y, \epsilon_s$ are on-axis strain components.

3. OFF-AXIS MODULUS

Because the composite laminates are made of off-axis and on-axis plies, the stiffness of off-axis ply orientation must be understood. The off-axis modulus of a ply can be determined in three steps: (i) the off-axis to on-axis strain transformation; (ii) the on-axis stress strain relation; and (iii) the on-axis to off-axis stress transformation. This process is initiated by a given strain in Fig. III(a) and leads us eventually to the induced stress in Fig. III(d). The above mentioned three transformations when combined together will yield the required off-axis modulus and off-axis stress strain relations for arbitrary angle of rotation.

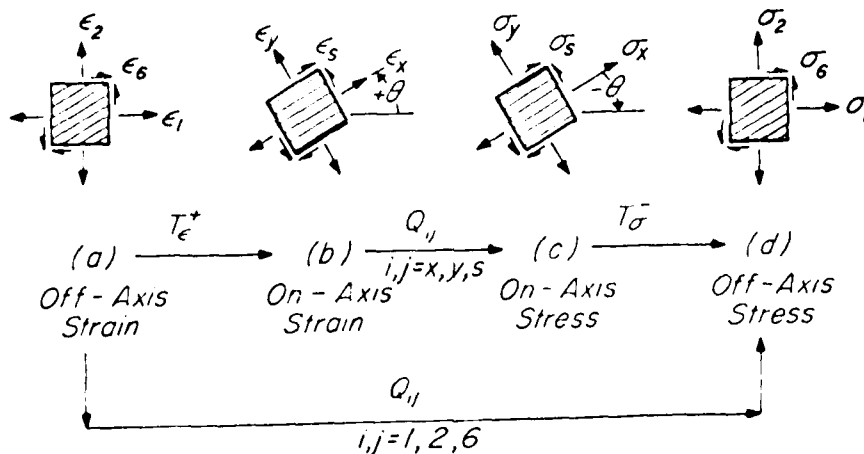


Fig. III: Determination of off-axis modulus

From (a)-(b): Use positive angle θ strain transformations

From (b)-(c): Use the on-axis stress strain relations in modulus

From (c)-(d): Use inverse stress transformation.

Following the above transformations and making some mathematical simplifications, off-axis stress strain relations can be obtained; i.e., Table 6:

Table 6: Off-axis stress strain relations

	ϵ_1	ϵ_2	ϵ_6
σ_1	Q_{11}	Q_{12}	Q_{16}
σ_2	Q_{21}	Q_{22}	Q_{26}
σ_6	Q_{61}	Q_{62}	Q_{66}

Where the off-axis modulus components are given in the matrix form shown in Table 7:

Table 7: Modulus components Q_{ij}

	1	U_2	U_3
Q_{11}	U_1	$\cos 2\theta$	$\cos 4\theta$
Q_{22}	U_1	$-\cos 2\theta$	$\cos 4\theta$
Q_{12}	U_4		$-\cos 4\theta$
Q_{66}	U_5		$-\cos 4\theta$
Q_{16}		$\frac{1}{2} \sin 2\theta$	$\sin 4\theta$
Q_{26}		$\frac{1}{2} \sin 2\theta$	$-\sin 4\theta$

Where

$$\begin{aligned}
 U_1 &= (3Q_{xx} + 3Q_{yy} + 2Q_{xy} + 4Q_{ss})/8 \\
 U_2 &= (Q_{xx} - Q_{yy})/2 \\
 U_3 &= (Q_{xx} + Q_{yy} - 2Q_{xy} - 4Q_{ss})/8 \\
 U_4 &= (Q_{xx} + Q_{yy} + 6Q_{xy} - 4Q_{ss})/8 \\
 U_5 &= (Q_{xx} + Q_{yy} - 2Q_{xy} + 4Q_{ss})/8
 \end{aligned}$$

4. INPLANE STIFFNESS OF SYMMETRIC LAMINATES

The composite laminates having a symmetry of stacking sequence about the midplane surface are considered. Such laminates behave as a homogeneous anisotropic plate. The effective modulus of the composite laminates is simply the arithmetic average of the modulus of the constituent plies. Simple formulae can be derived to compute effective modulus in terms of the moduli of constituent plies. It has been found that the stiffness properties of bidirectional laminates can be fundamentally different from conventional materials. The main stress strain relations for a composite laminate are presented in Tables 8 and 9.

Table 8: Stress strain relations - modulus

	ϵ_1^o	ϵ_2^o	ϵ_6^o
N_1	A_{11}	A_{12}	A_{16}
N_2	A_{21}	A_{22}	A_{26}
N_6	A_{61}	A_{62}	A_{66}

Table 9: Stress strain relations - compliance

	N_1	N_2	N_6
ϵ_1^0	a_{11}	a_{12}	a_{16}
ϵ_2^0	a_{21}	a_{22}	a_{26}
ϵ_6^0	a_{61}	a_{62}	a_{66}

Where N_1 , N_2 , and N_6 are stress resultants over the thickness (h) of the laminate and are defined by

$$N_i = \int_{-h/2}^{h/2} \sigma_i dz, \quad (i = 1, 2, 6) \quad (3)$$

$$\text{or} \quad N_i = \int_{-h/2}^{h/2} \sum_j Q_{ij} \epsilon_j^0 dz, \quad (j = 1, 2, 6)$$

and ϵ_i^0 ($i = 1, 2, 6$) are inplane strain components, constant through the thickness. A laminate consisting of various angle plies will contain different values of Q_{ij} through the thickness. Thus the different laminates have different stiffness properties. The relations 3, after going through some mathematical simplifications, reduce to relations of Table 8, where A_{ij} are given in Table 10.

Table 10: Modulus components, A_{ij}

	1	U_2	U_3
A_{11}/h	U_1	V_1^*	V_2^*
A_{22}/h	U_1	$-V_1^*$	V_2^*
A_{12}/h	U_4		$-V_2^*$
A_{66}/h	U_5		$-V_2^*$
A_{16}/h		$\frac{1}{2} V_3^*$	V_4^*
A_{26}/h		$\frac{1}{2} V_3^*$	$-V_4^*$

In which U_i ($i = 1, 2, \dots, 5$) are given in Eq. 2, and

$$V_{(1,2,3,4)}^* = \frac{1}{h} \int_{-h/2}^{h/2} (\cos 2\theta, \cos 4\theta, \sin 2\theta, \sin 4\theta) dz \quad (4)$$

For known values of A_{ij} in Table 8, the values of a_{ij} in Table 9 can be obtained. In the foregoing formulation it has been assumed that the laminate is made of plies of the same material. With the given material properties E_x , E_y , E_s , and ν_{xy} of a uniaxial ply, the elements of matrices (8) and (9) (i.e., A_{ij} and a_{ij}) can be computed. Since N_1 , N_2 , and N_6 are stress resultants over the thickness of the laminate, the stress strain relations, Tables 8 and 9, can be rewritten as Tables 11 and 12.

Table 11: Stress strain relations - modulus

	ϵ_1^o	ϵ_2^o	ϵ_6^o
$\bar{\sigma}_1$	A_{11}/h	A_{12}/h	A_{16}/h
$\bar{\sigma}_2$	A_{21}/h	A_{22}/h	A_{26}/h
$\bar{\sigma}_6$	A_{61}/h	A_{62}/h	A_{66}/h

Table 12: Stress strain relations - compliance

	$\bar{\sigma}_1$	$\bar{\sigma}_2$	$\bar{\sigma}_6$
ϵ_1^o	$h a_{11}$	$h a_{12}$	$h a_{16}$
ϵ_2^o	$h a_{21}$	$h a_{22}$	$h a_{26}$
ϵ_6^o	$h a_{61}$	$h a_{62}$	$h a_{66}$

Where $\bar{\sigma}_i$ ($= \frac{N_i}{h}$) are average inplane stress components, A_{ij}/h are modulus components and $h a_{ij}$ are compliance components of the laminate. The engineering constants for the laminate are defined as follows:

$$\begin{aligned}
 E_1^o &= 1/h a_{11} \\
 E_2^o &= 1/h a_{22} \\
 E_6^o &= 1/h a_{66} \\
 \nu_{21}^o &= -a_{21}/a_{11} \\
 \nu_{12}^o &= -a_{12}/a_{22} \\
 \nu_{16}^o &= a_{16}/a_{66}
 \end{aligned} \tag{5}$$

$$\nu_{61}^{\circ} = a_{61}/a_{11}$$

$$\nu_{26}^{\circ} = a_{26}/a_{66}$$

$$\nu_{62}^{\circ} = a_{62}/a_{22}$$

The E,s and ν ,s are engineering constants analogous to those defined in Eq. 1, a subscript denotes the corresponding direction and the superscript '°' indicates that the material property is for a laminate.

The stress strain relations in Table 12 can be rewritten in terms of engineering constants in the following form:

Table 13: Stress strain relations - engineering constants

	$\bar{\sigma}_1$	$\bar{\sigma}_2$	$\bar{\sigma}_6$
ϵ_1°	$\frac{1}{E_1^{\circ}}$	$-\frac{\nu_{12}^{\circ}}{E_2^{\circ}}$	$\frac{\nu_{16}^{\circ}}{E_6^{\circ}}$
ϵ_2°	$-\frac{\nu_{21}^{\circ}}{E_1^{\circ}}$	$\frac{1}{E_2^{\circ}}$	$\frac{\nu_{26}^{\circ}}{E_6^{\circ}}$
ϵ_6°	$\frac{\nu_{61}^{\circ}}{E_1^{\circ}}$	$\frac{\nu_{62}^{\circ}}{E_2^{\circ}}$	$\frac{1}{E_6^{\circ}}$

Since the compliance matrix is symmetric, the following reciprocal relations can be easily derived:

$$\frac{E_1^{\circ}}{E_2^{\circ}} = \frac{\nu_{21}^{\circ}}{\nu_{12}^{\circ}} = \frac{a_{22}}{a_{11}} = a$$

$$\frac{E_1^{\circ}}{E_6^{\circ}} = \frac{\nu_{61}^{\circ}}{\nu_{16}^{\circ}} = \frac{a_{66}}{a_{11}} = b \quad (6)$$

$$\frac{E_2^{\circ}}{E_6^{\circ}} = \frac{\nu_{62}^{\circ}}{\nu_{26}^{\circ}} = \frac{a_{66}}{a_{22}} = c$$

a , b , c are called as Young's moduli ratios. Thus, all the formulae necessary for computation of stiffness properties of a general symmetric multidirectional composite have been given.

SECTION III

RESULTS

1. STIFFNESS

Modulus and compliance components, engineering constants and their ratios, and strengths of bidirectional laminates $(-\phi_{n_1}/\phi_{n_2})_s$ for various values of ϕ and their rotation (through angle γ) are computed. The on-axis material properties of T300/5208 material, considered in the present computations, are given in Table 15. The sign conventions for the ply angle ϕ and rotation angle γ are given in Figure I.

From Eq. 4, we can define V^* 's for all bidirectional laminates

$$\begin{aligned} V_1^* &= \frac{1}{n_1+n_2} [n_1 \cos 2\theta_1 + n_2 \cos 2\theta_2] \\ V_2^* &= \frac{1}{n_1+n_2} [n_1 \cos 4\theta_1 + n_2 \cos 4\theta_2] \\ V_3^* &= \frac{1}{n_1+n_2} [n_1 \sin 2\theta_1 + n_2 \sin 2\theta_2] \\ V_4^* &= \frac{1}{n_1+n_2} [n_1 \sin 4\theta_1 + n_2 \sin 4\theta_2] \end{aligned} \quad (7)$$

where

$$\begin{aligned} \theta_1 &= \gamma - \phi \\ \theta_2 &= \gamma + \phi \end{aligned} \quad (8)$$

For all combinations of laminates given in Table 1, six modulus components A_{ij}/h , six compliance components $h a_{ij}$, nine engineering constants E° 's and ν° 's; and three moduli ratios are computed. Each figure contains the addressed material property for seven combinations of volume fractions of the angle plies.

2. STRENGTH

Tensor polynomial failure criterion has been used to predict the strength of bidirectional laminates. First ply failure stress is considered as the strength of the laminate. The effect of ply orientation, volume fraction, and laminate rotation on strength of the laminates has been investigated. The details of the use of tensor polynomial failure criterion are given in References 1 and 2. Strengths of bidirectional laminates due to the following loading patterns are computed:

Table 14: Point loading patterns considered

Case No.	$\bar{\sigma}_1$	$\bar{\sigma}_2$	$\bar{\sigma}_6$	Notation
1	N	o	o	(N,o,o)
2	N	N	o	(N,N,o)
3	N	-N	o	(N,-N,o)
4	o	o	N	(o,o,N)
5	N	o	N	(N,o,N)
6	N	o	-N	(N,o,-N)

In all these cases, the parameter N at which the first ply of the T300/5203 composite laminate fails is calculated.

Table 15: Material properties of T300/5208

E_x	=	181.0 GPa
E_y	=	10.3 GPa
ν_{xy}	=	0.28
E_s	=	7.17 GPa
X	=	1500 MPa
X'	=	1500 MPa
Y	=	40 MPa
Y'	=	246 MPa
S	=	68 MPa

X, X' = Longitudinal tensile and compressive strengths

Y, Y' = Transverse tensile and compressive strengths

S = Shear strength

3. ILLUSTRATIONS

There are two types of parametric variations we have made with respect to angle ply ϕ and angle of rotation γ . One type consists of fixing the ply angle ϕ and computing the results for various rotations ($-90 \leq \gamma \leq 90$). The second type consists of varying ply angle ϕ , i.e., ($-90 \leq \phi \leq 90$), for a fixed value of rotation γ . For explaining this procedure for using the data available in this report in graphical form, we pick up one case of each of the above mentioned two types of variations.

Fig. IV contains E_2^0 for various laminates with $\gamma=75^\circ$. In this figure the abscissa denotes the ply angle (ϕ) in degrees, the ordinate denotes the transverse Young's modulus E_2^0 in GPa, and γ denotes the angle, in degrees of counterclockwise rotation of the laminate. The values of E_2^0 for laminates with a value $\phi = -15^\circ$ are given in Table 16. Similarly, in Fig. V, the angular rotation γ is the abscissa and $h_{a_{11}}$ is the ordinate for laminates with $\phi=30^\circ$. The results for $h_{a_{11}}$ pertaining to different laminates with $\gamma = -60^\circ$ are given in Table 17. Thus it is simple to use the data given in the figures.

Table 16: Values of transverse Young's modulus E_2^* for different volume fractions of bidirectional laminates as obtained from Fig. IV; $\phi = -15^\circ$, $\gamma = 75^\circ$

Symbol in Plot	n_1	n_2	Laminate with $\phi = -15^\circ$, $\gamma = 75^\circ$	E_2 (GPa)
Δ	1	0	60	28
+	9	1	$(60_9/90_1)_s$	46
X	4	1	$(60_4/90_1)_s$	61
\diamond	1	1	$(60_1/90_1)_s$	110
\uparrow	1	4	$(60_1/90_4)_s$	156
\times	1	9	$(60_1/90_9)_s$	171
Z	0	1	90	186

Table 17: Values of compliance component ha_{11} for different volume fractions of bidirectional laminates as obtained from Fig. V; $\phi=30^\circ$, $\gamma=-60^\circ$

Symbol in Plot	n_1	n_2	Laminate for $\phi=30^\circ$, $\gamma=-60^\circ$	$ha_{11}(\text{TPa})^{-1}$
Δ	1	0	-90	95
+	9	1	$(-90_9/-30_1)_s$	58
\times	4	1	$(-90_4/-30_1)_s$	48
\diamond	1	1	$(-90_1/-30_1)_s$	38
∇	1	4	$(-90_1/-30_4)_s$	35
\boxtimes	1	9	$(-90_1/-30_9)_s$	35
Σ	0	1	-30	35

SECTION IV

CONCLUSIONS

This report gives components of modulus and compliance matrices, engineering constants and their ratios, and strengths of different bidirectional symmetric laminates made of T300/5208 material. This enables the designer to pick up the laminate with ply orientations and volume fractions satisfying the desired stiffness and strength requirements. This work also shows the user the capabilities of composites that can be achieved by varying ply orientations and volume fraction. This understanding helps the use of sites for optimum component design applications.

REFERENCES

1. S.W. Tsai and H.T. Hahn, Introduction to Composite Materials, Technomic Publishing Co., Westport, CT 06880, July 1980.
2. S.W. Tsai and H.T. Hahn, TI-59 Magnetic Card Calculator Solutions to Composite Materials, Air Force Materials Laboratory Report, AFML-TR-79-4040, April 1979.

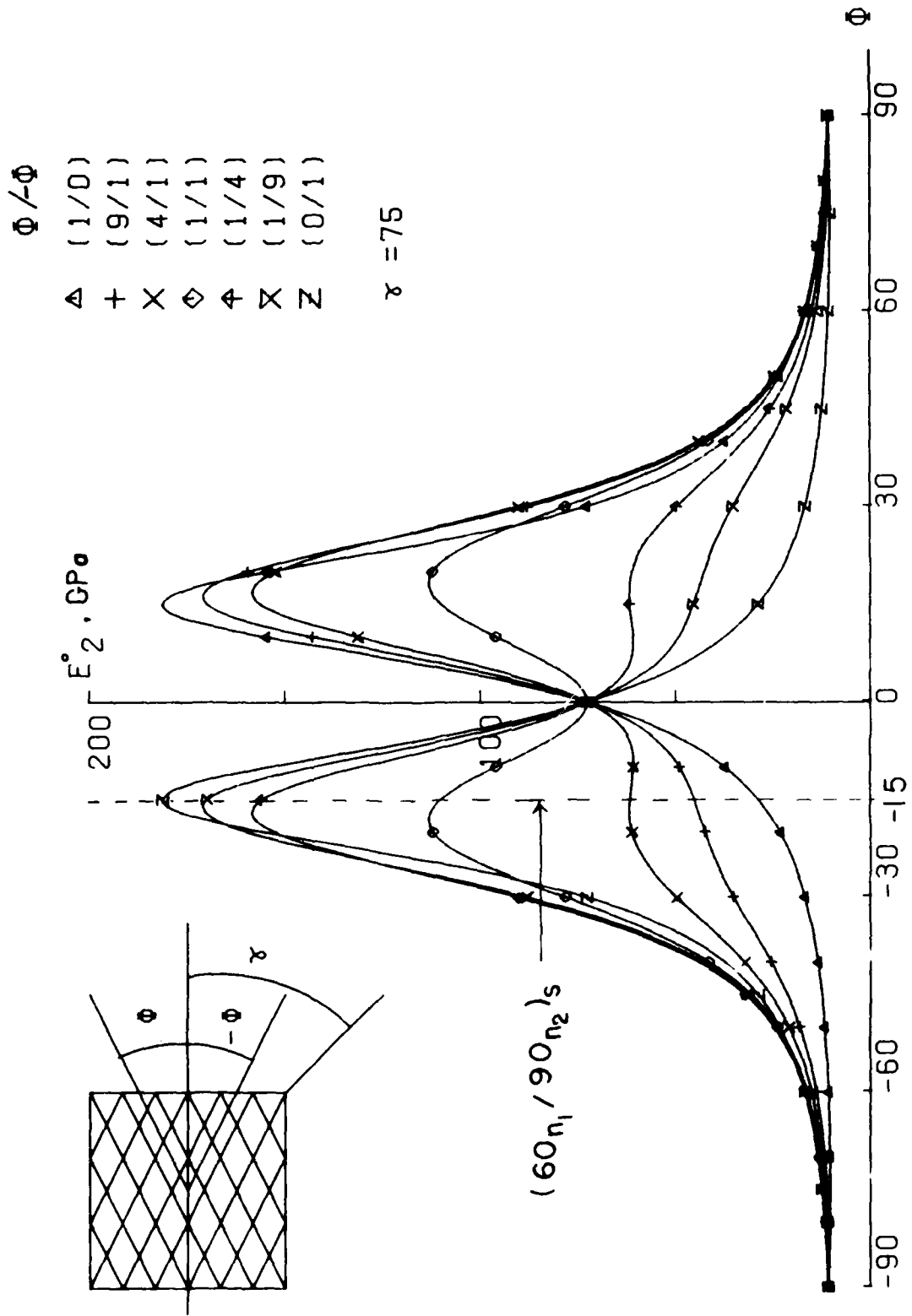
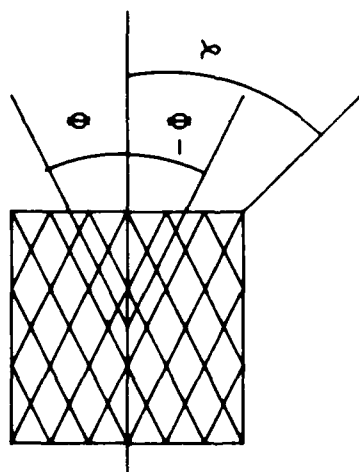


FIG.: IV TRANSVERSE YOUNG'S MODULUS E_2' VERSUS PLY ANGLE Φ OF THE LAMINATE FOR VARIOUS VOLUME FRACTIONS.



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \clubsuit (1/4)
 \bowtie (1/9)
 Σ (0/1)

$\Phi = 30$

$Q_{11}h, (TP_0)^{-1}$

$\leftarrow (-90n_1/-30n_2)s$

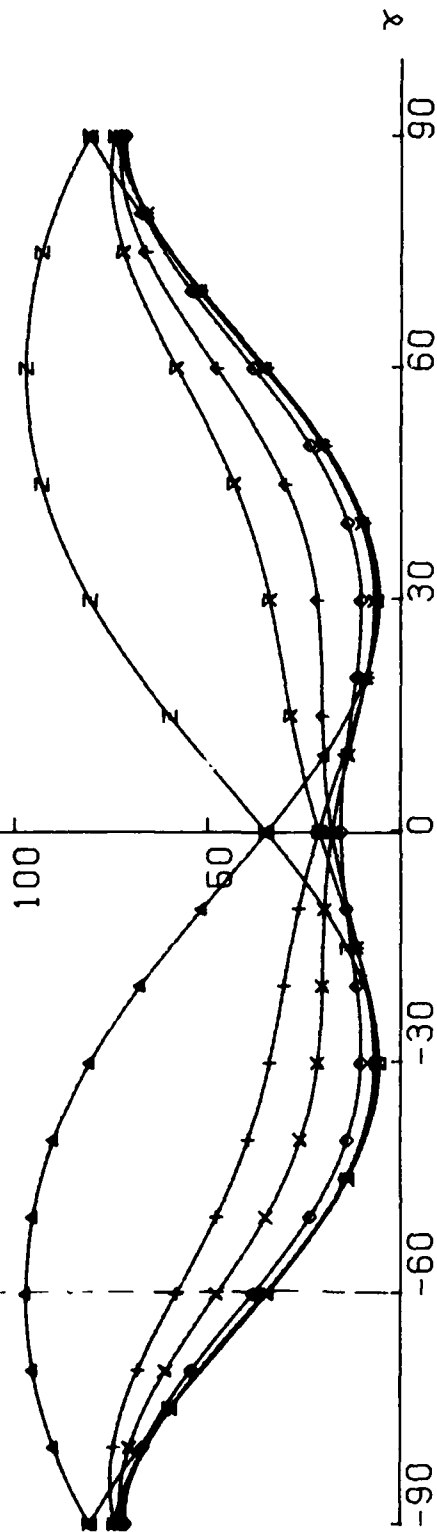


FIG.: V COMPLIANCE COMPONENT hQ_{11} VERSUS ROTATION FOR VARIOUS VOLUME FRACTIONS.

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 Δ (0/1)
 $\Phi = 22.5$

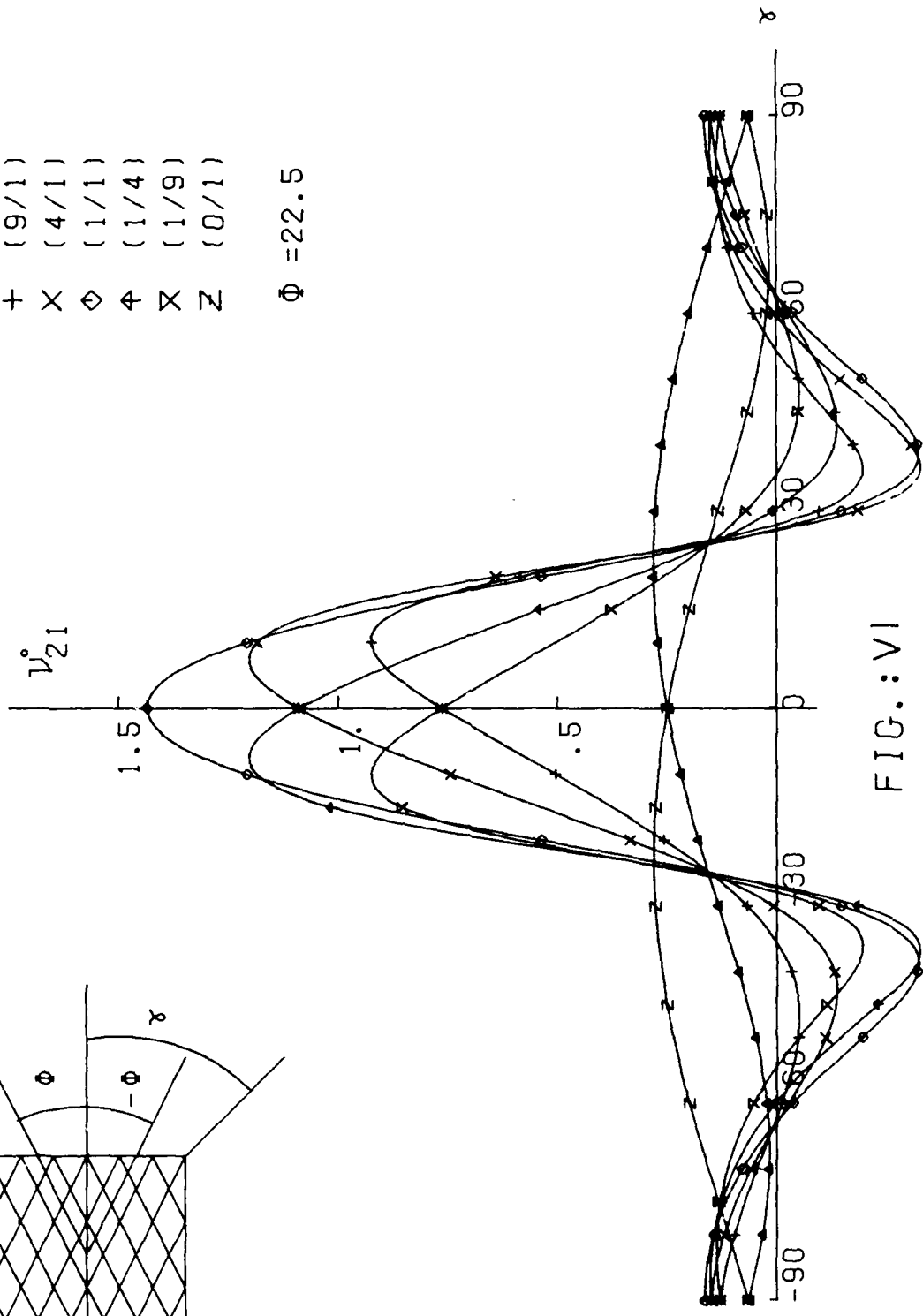
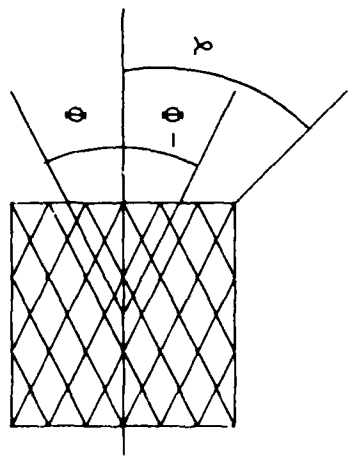


FIG.:VI

LONGITUDINAL POISSON'S RATIO FOR BIDIRECTIONAL LAMINATES.

COMPONENTS OF MODULUS MATRIX FOR DIFFERENT BIDIRECTIONAL LAMINATES

COMPONENT FIGURE NOS.

A ₁₁	1-16
A ₂₂	17-32
A ₁₂	33-48
A ₆₆	49-64
A ₁₆	65-80
A ₂₆	81-96

Φ/Φ
 (1/0)
 (9/1)
 (4/1)
 (1/1)
 (1/4)
 (1/9)
 (0/1)

Δ + X \diamond \oplus X Z

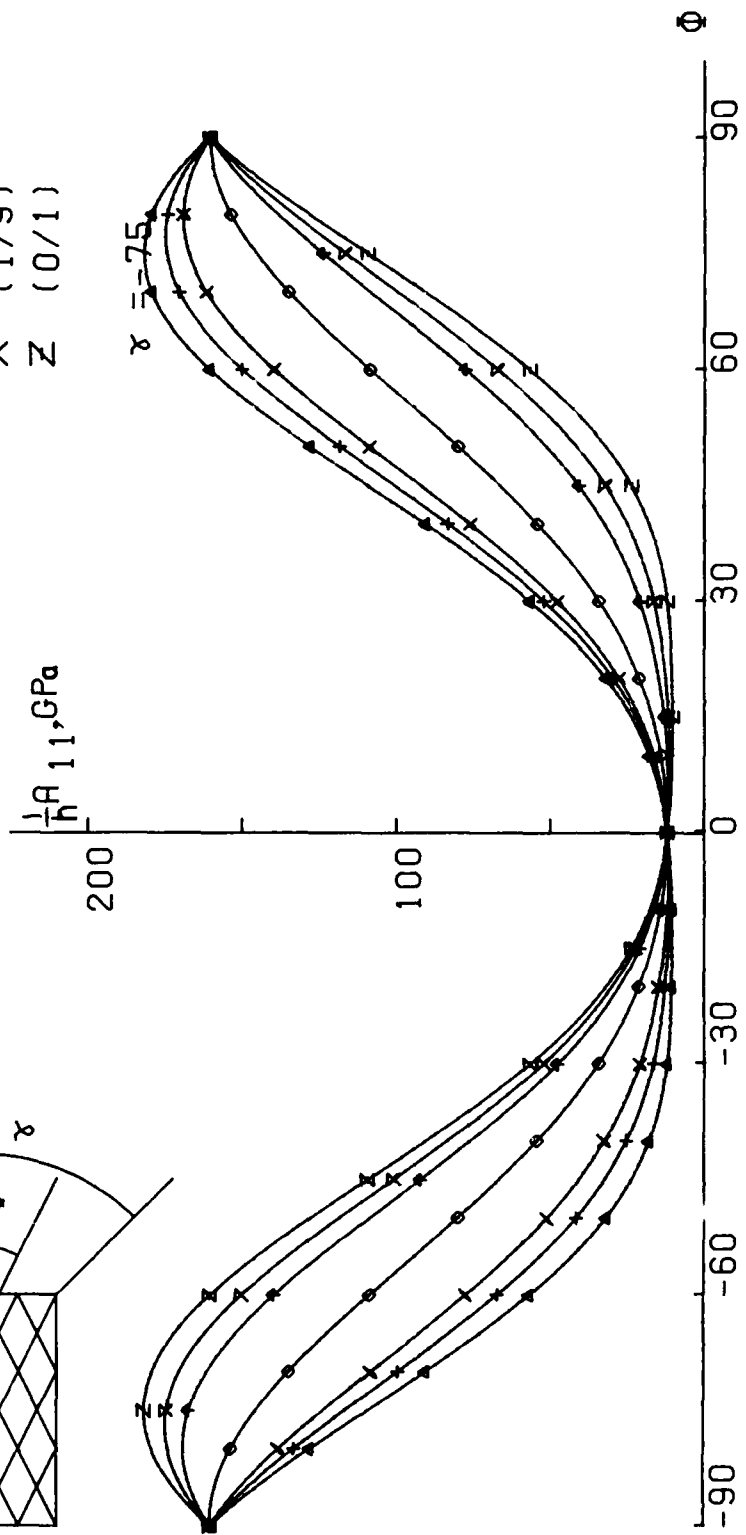
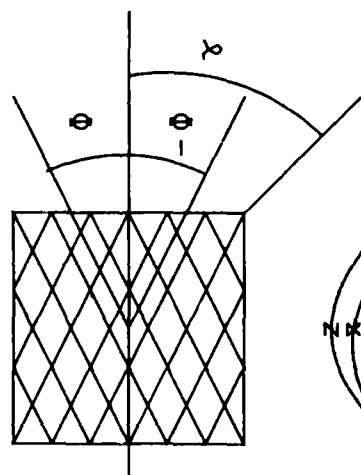


FIG.:1

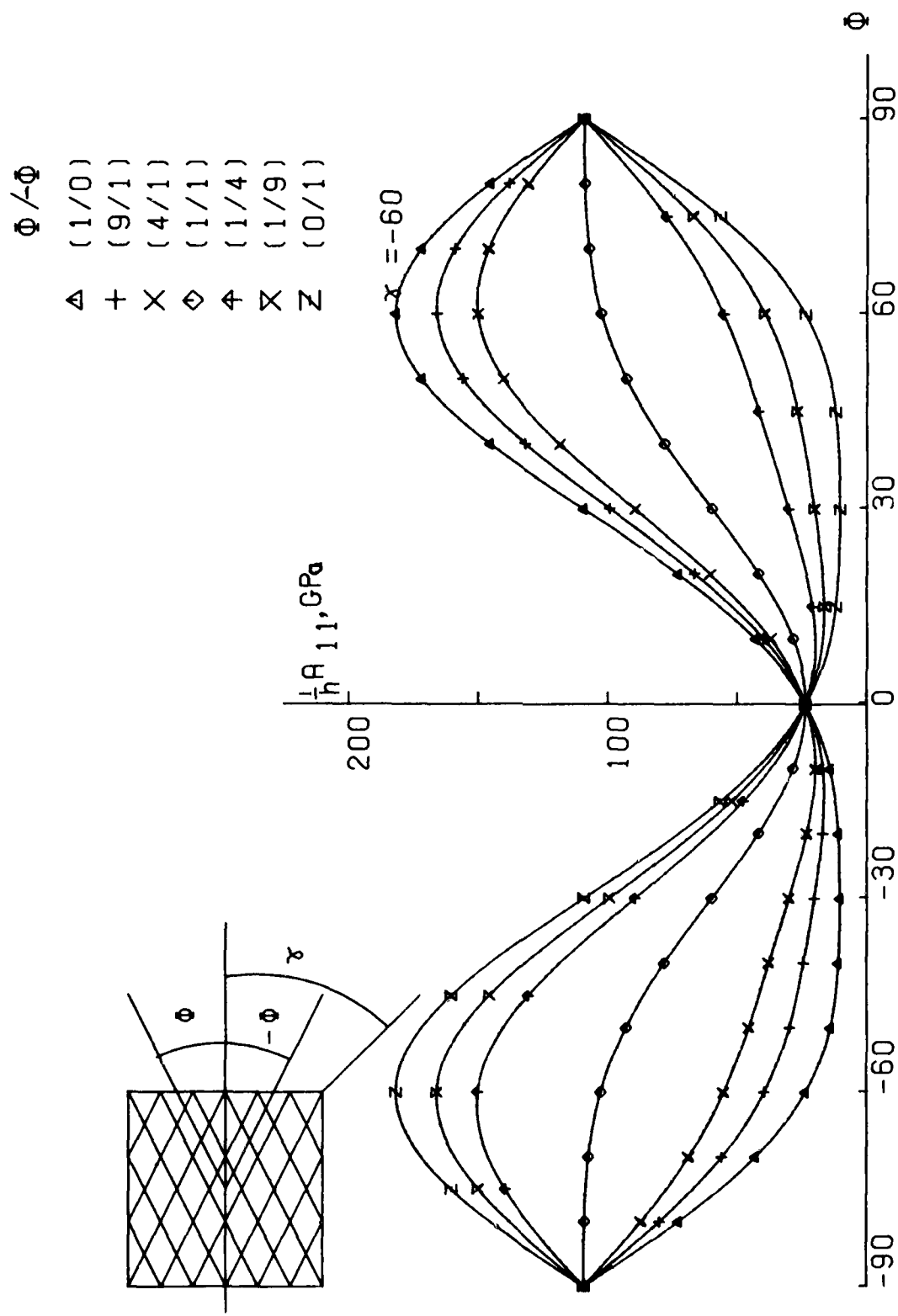


FIG.:2

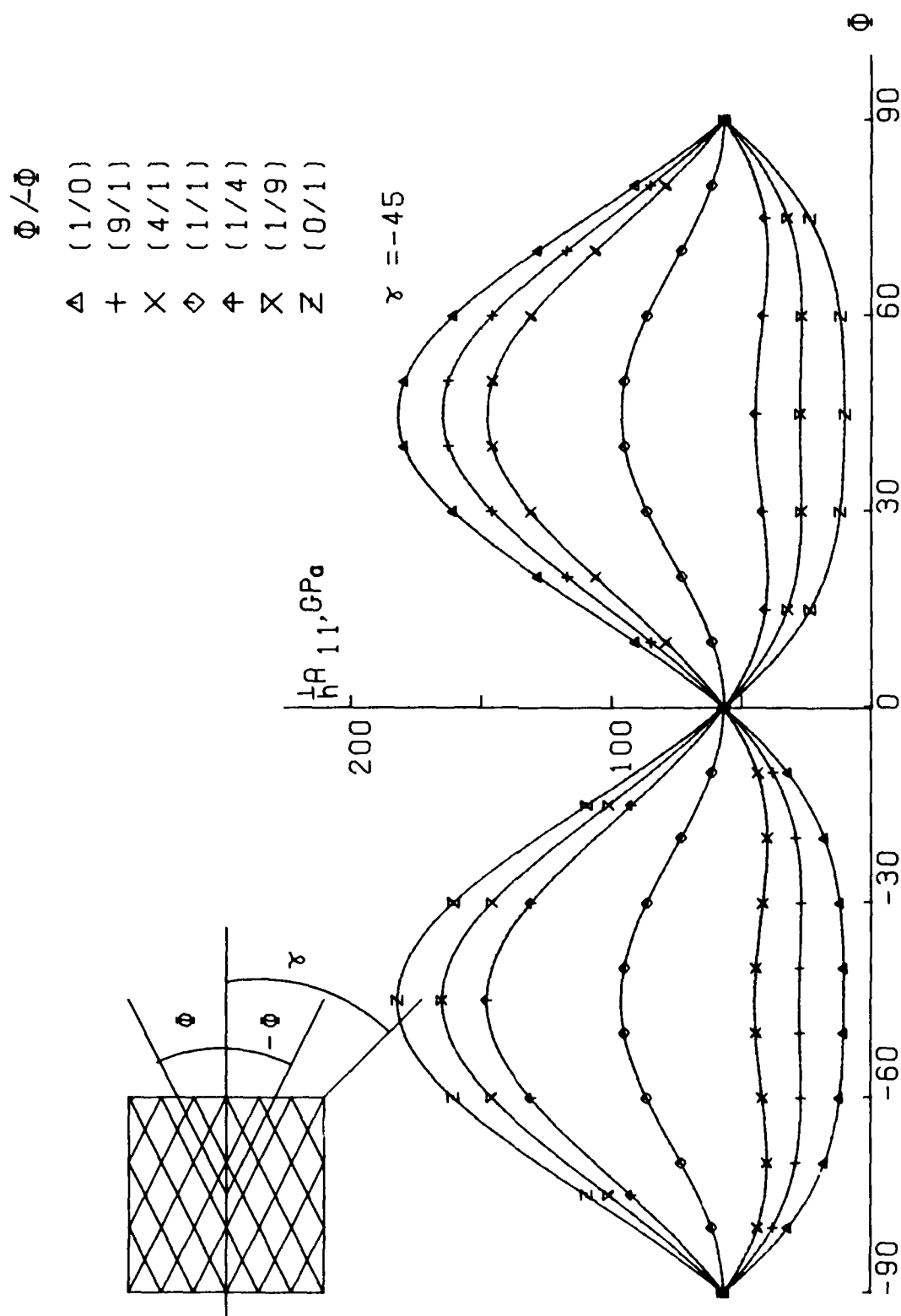


FIG.:3

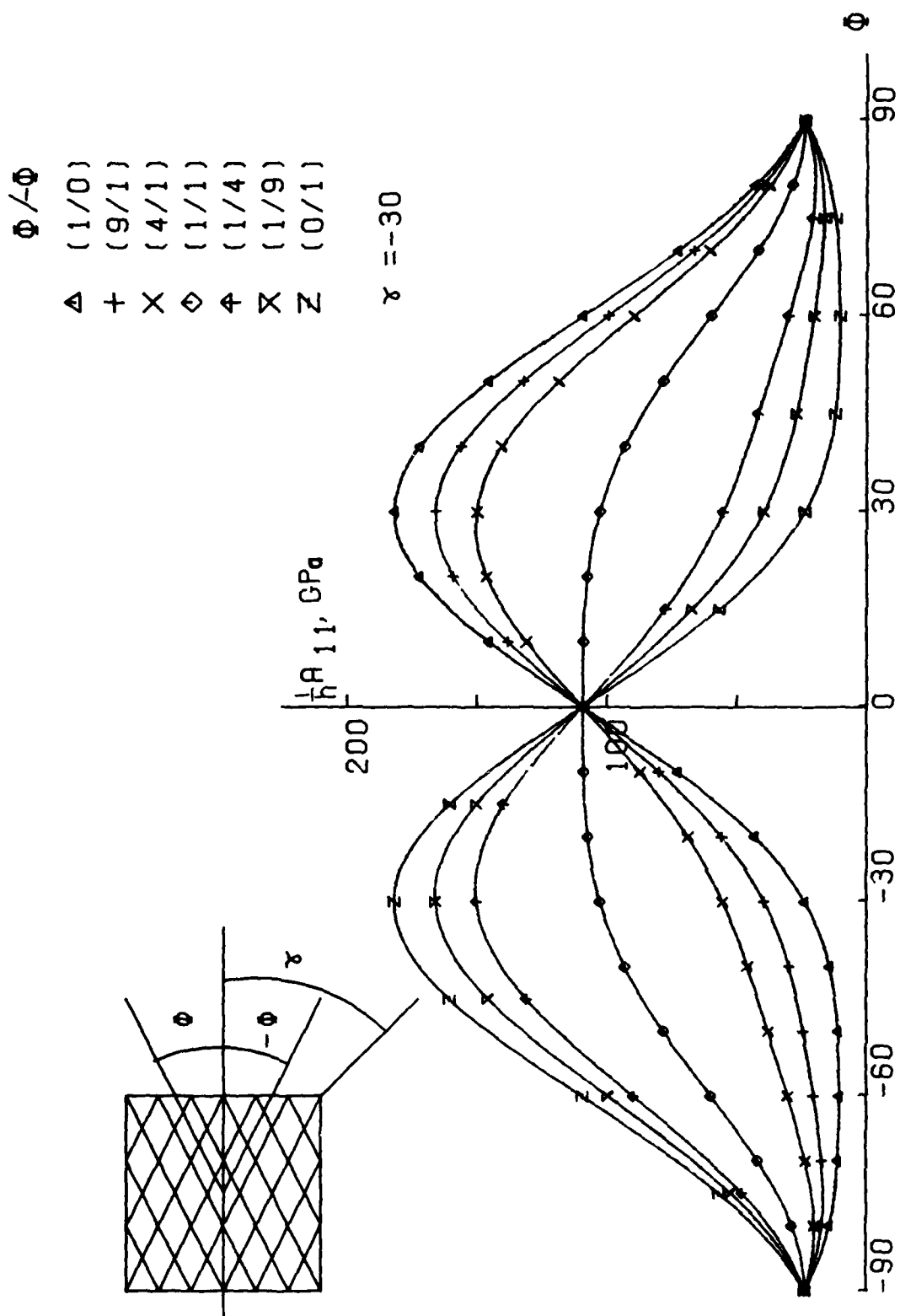


FIG.: 4

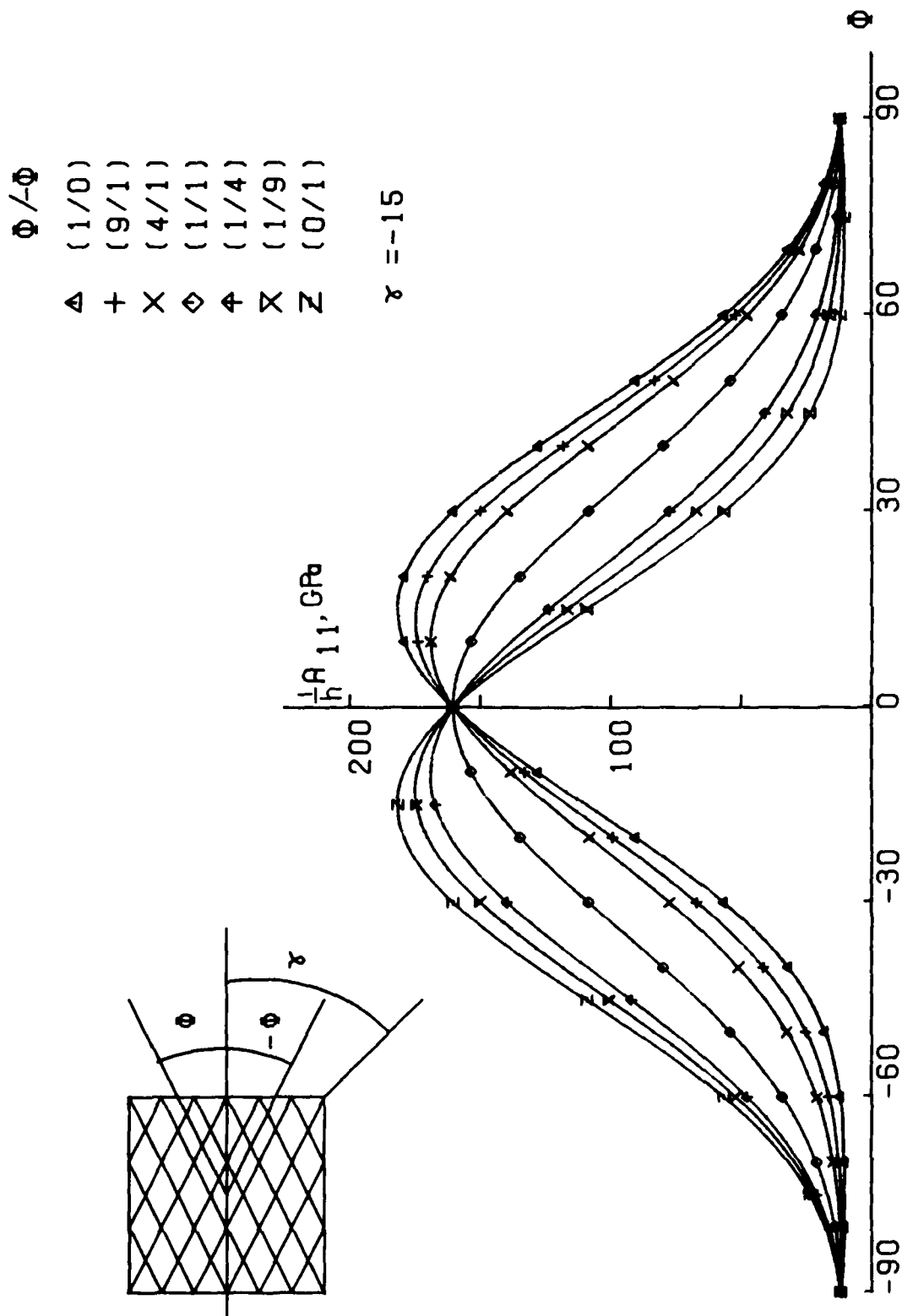


FIG.:5

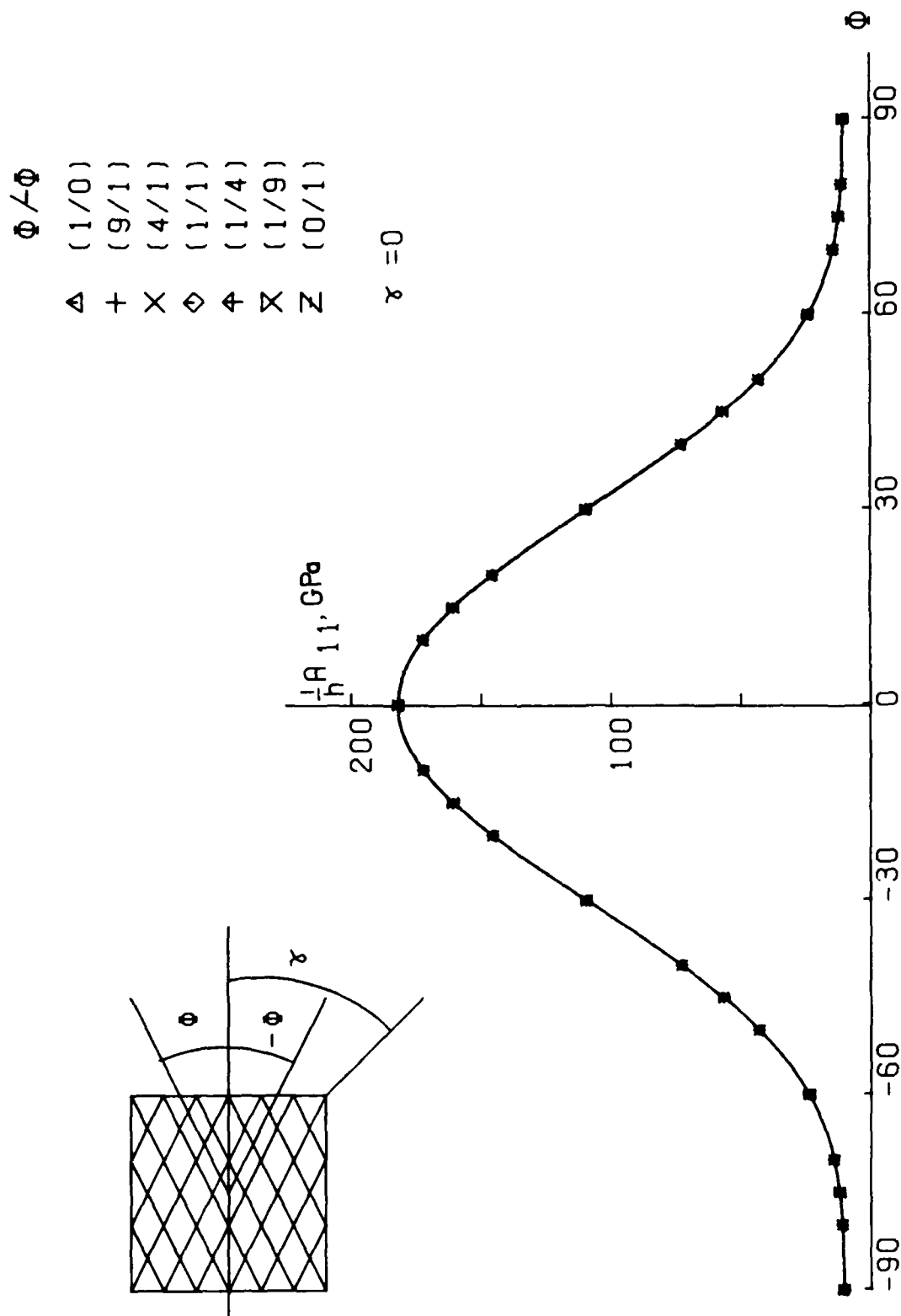


FIG.:6

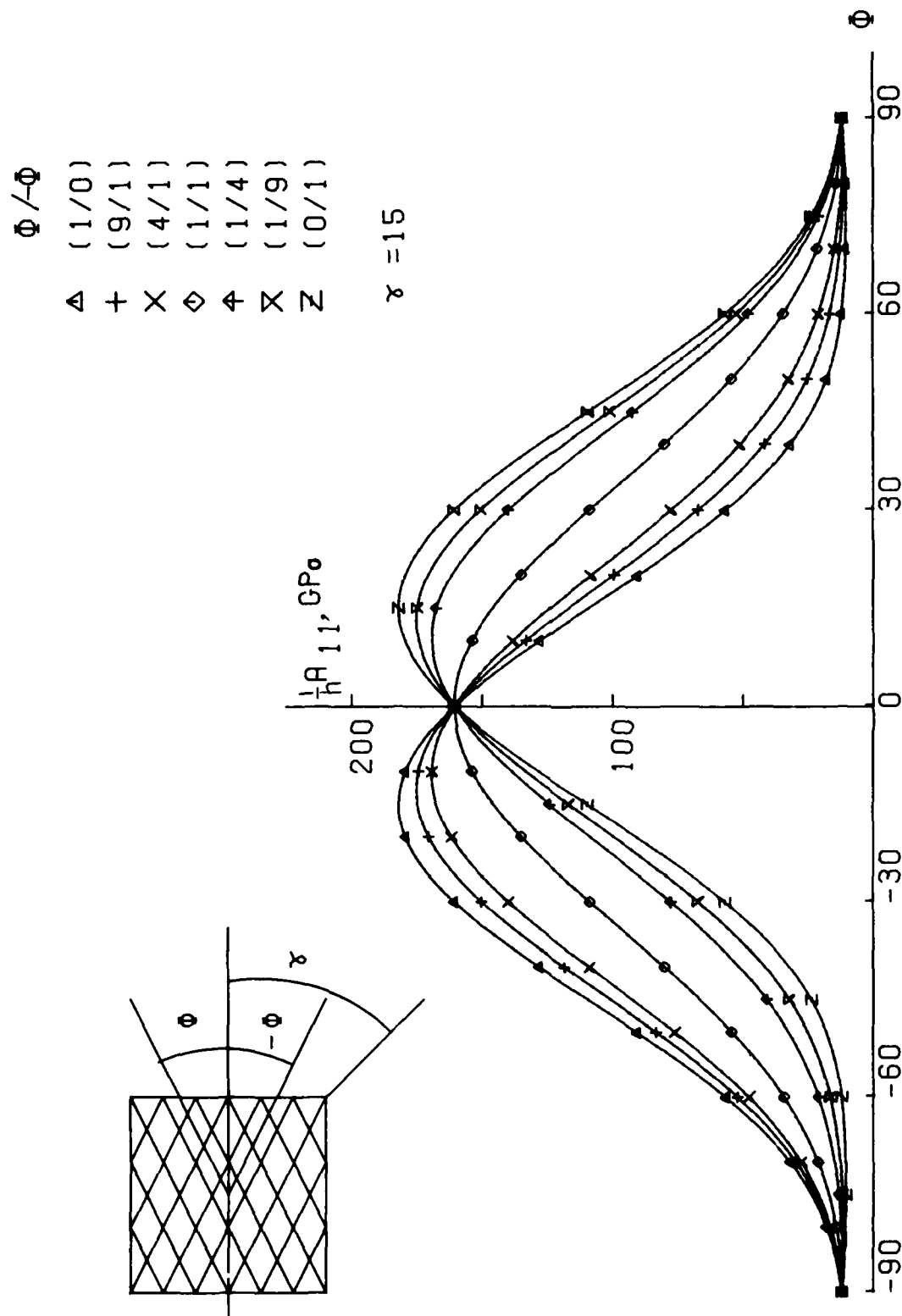


FIG.:7

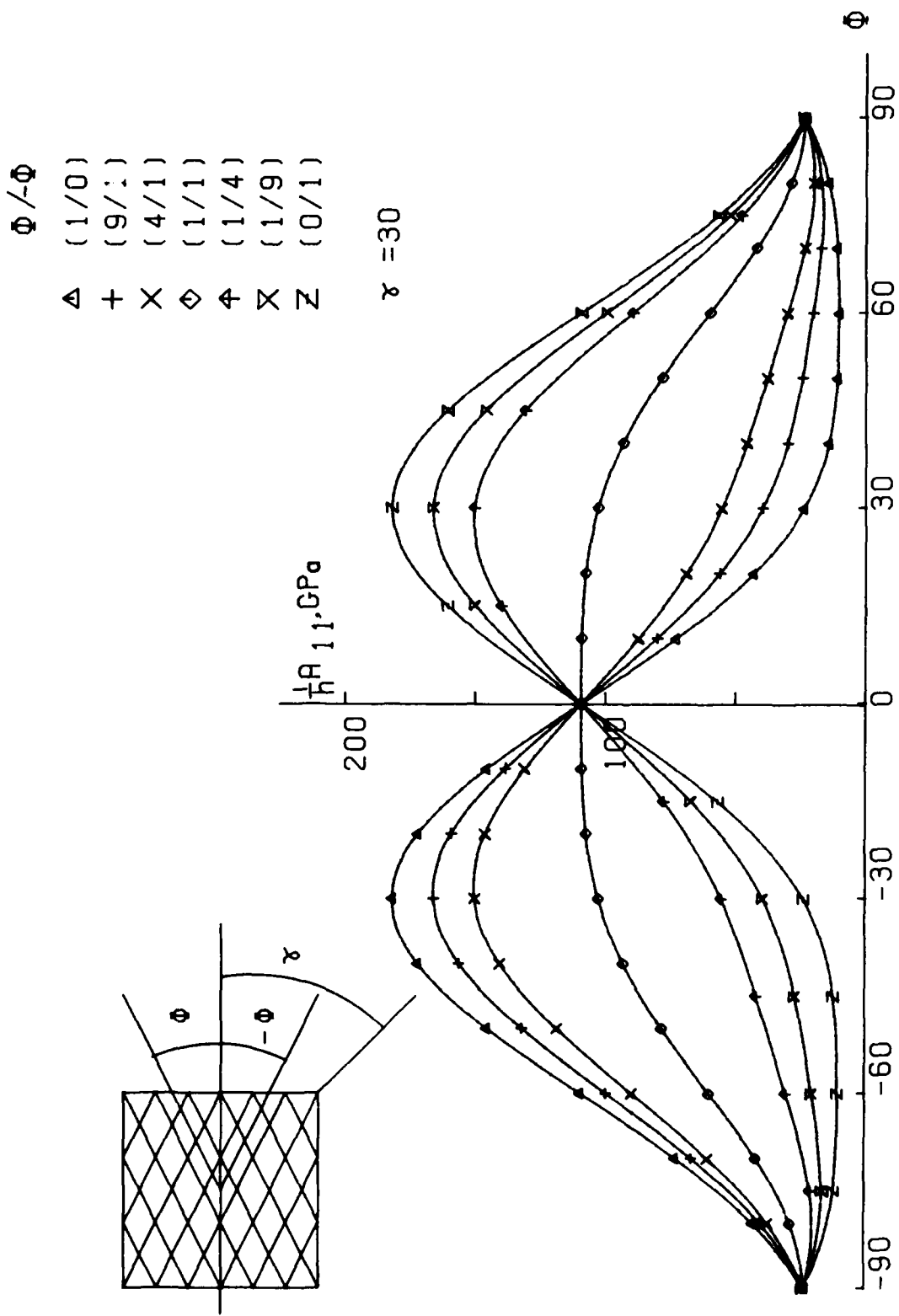


FIG.:8

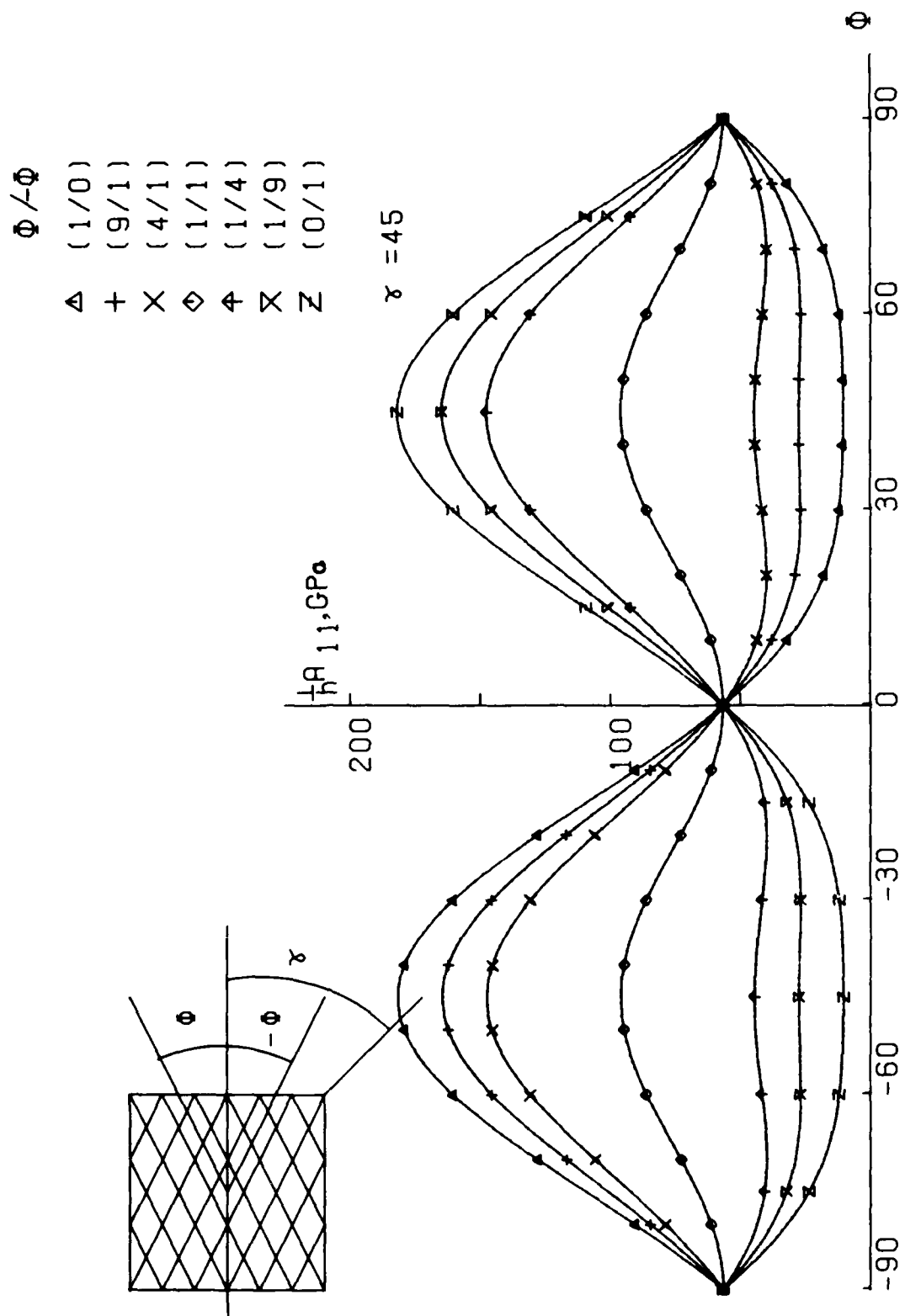


FIG.:9

ϕ/ϕ
 $(1/0)$
 $(9/1)$
 $(4/1)$
 $(1/1)$
 $(1/4)$
 $(1/9)$
 $(0/1)$

Δ + X \diamond ∇ X Z

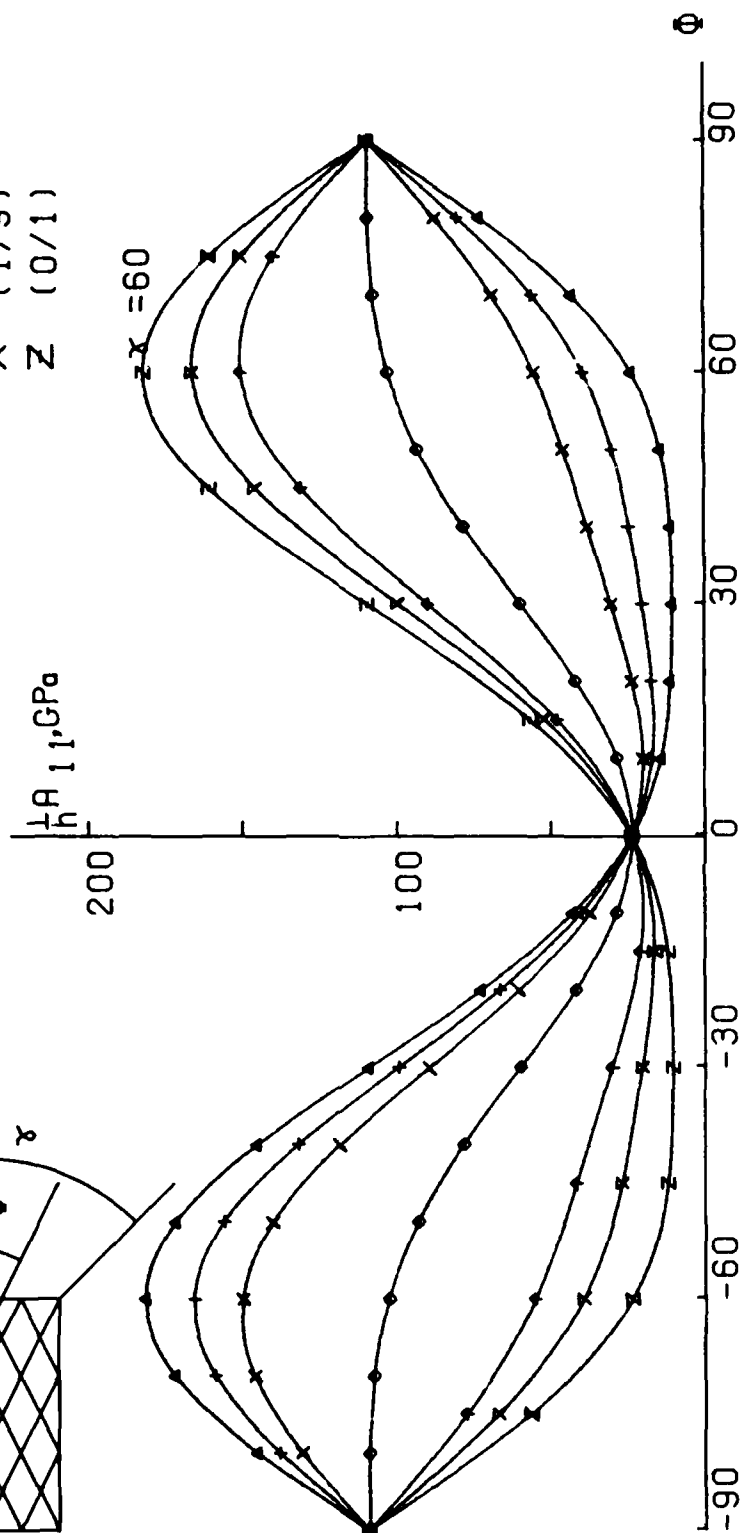
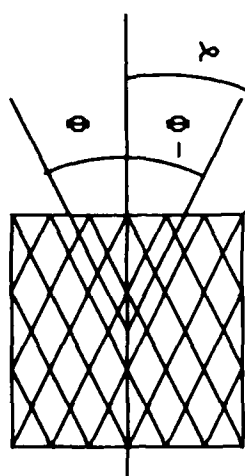


FIG.:10

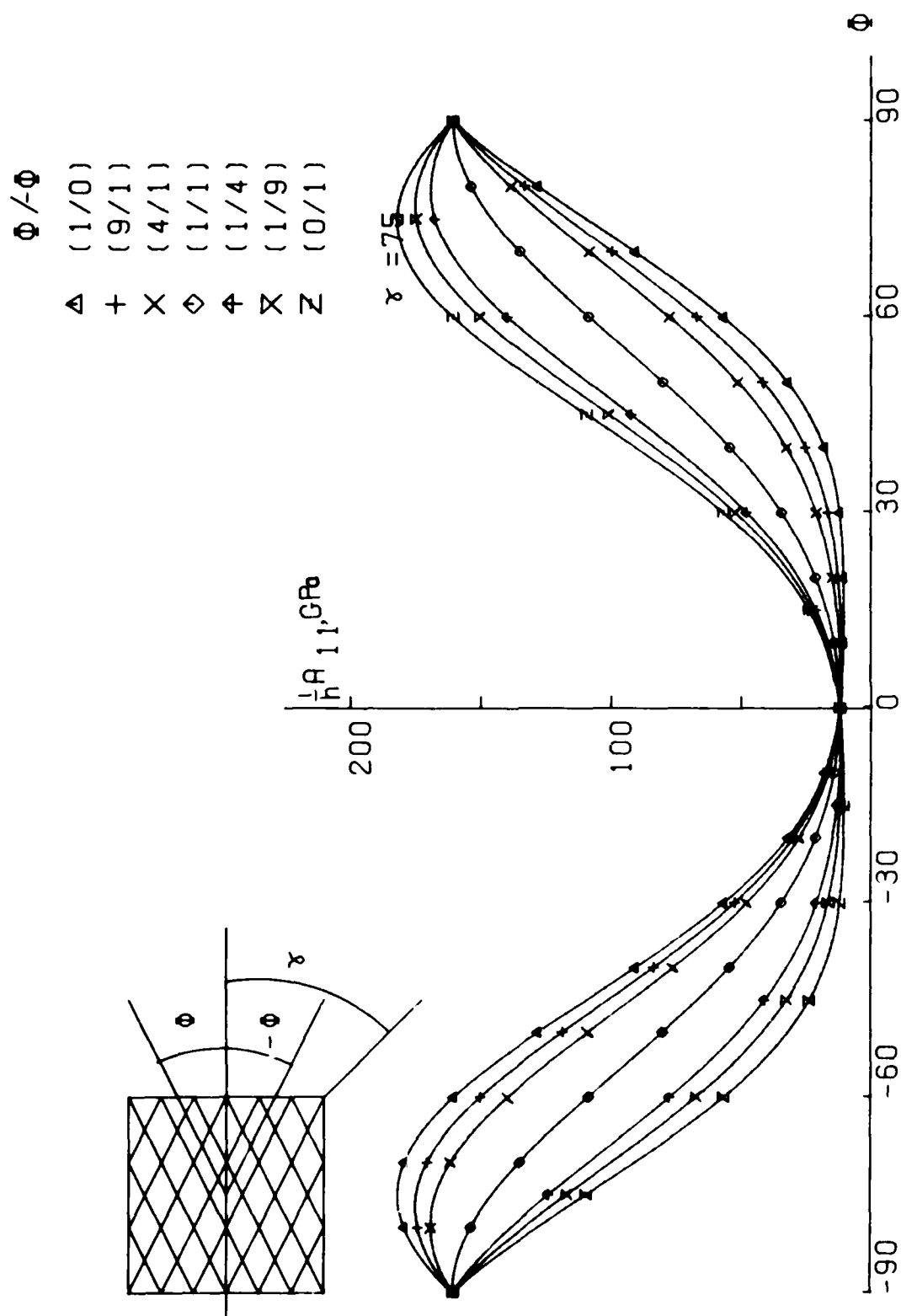


FIG.:11

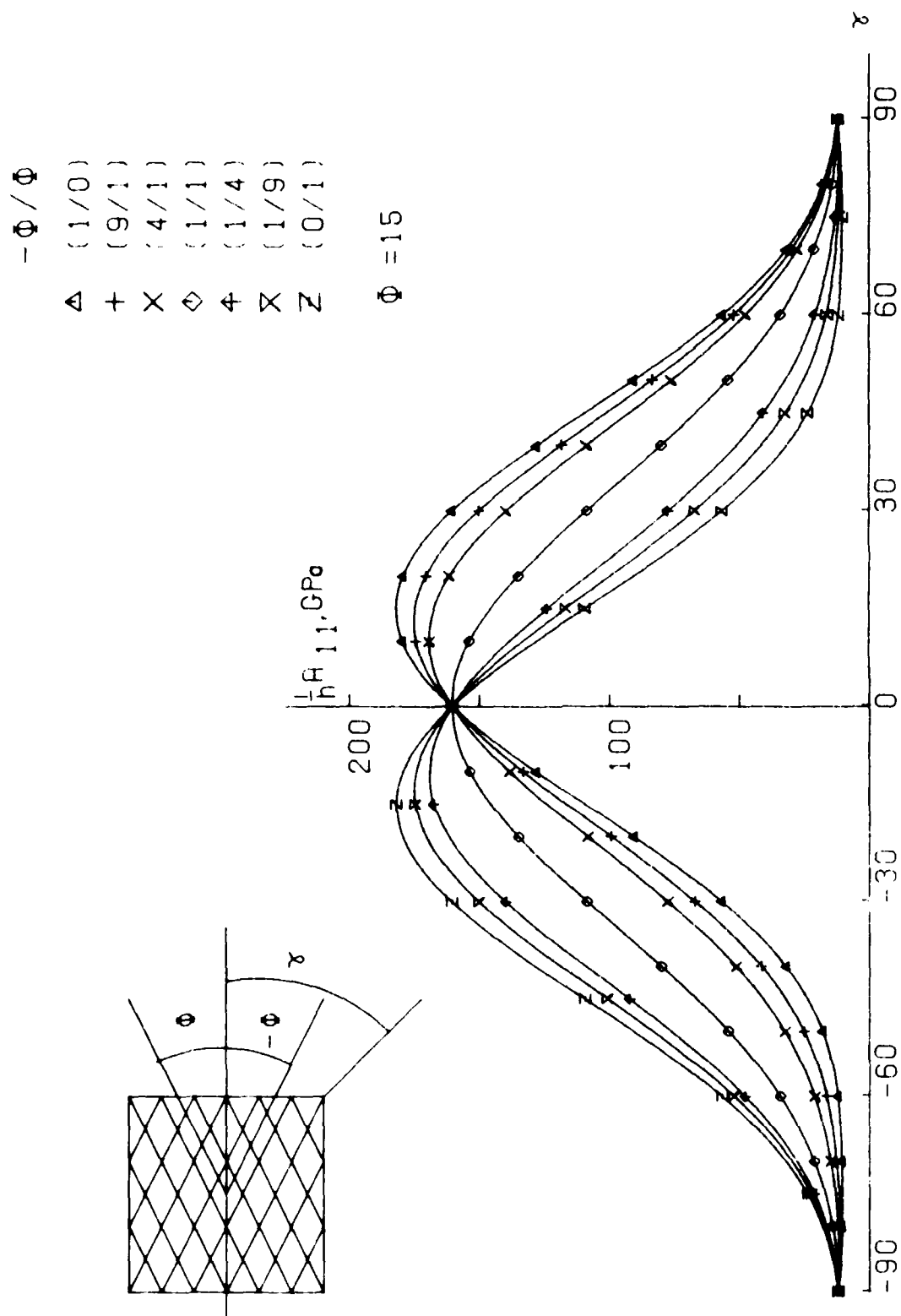


FIG.:12

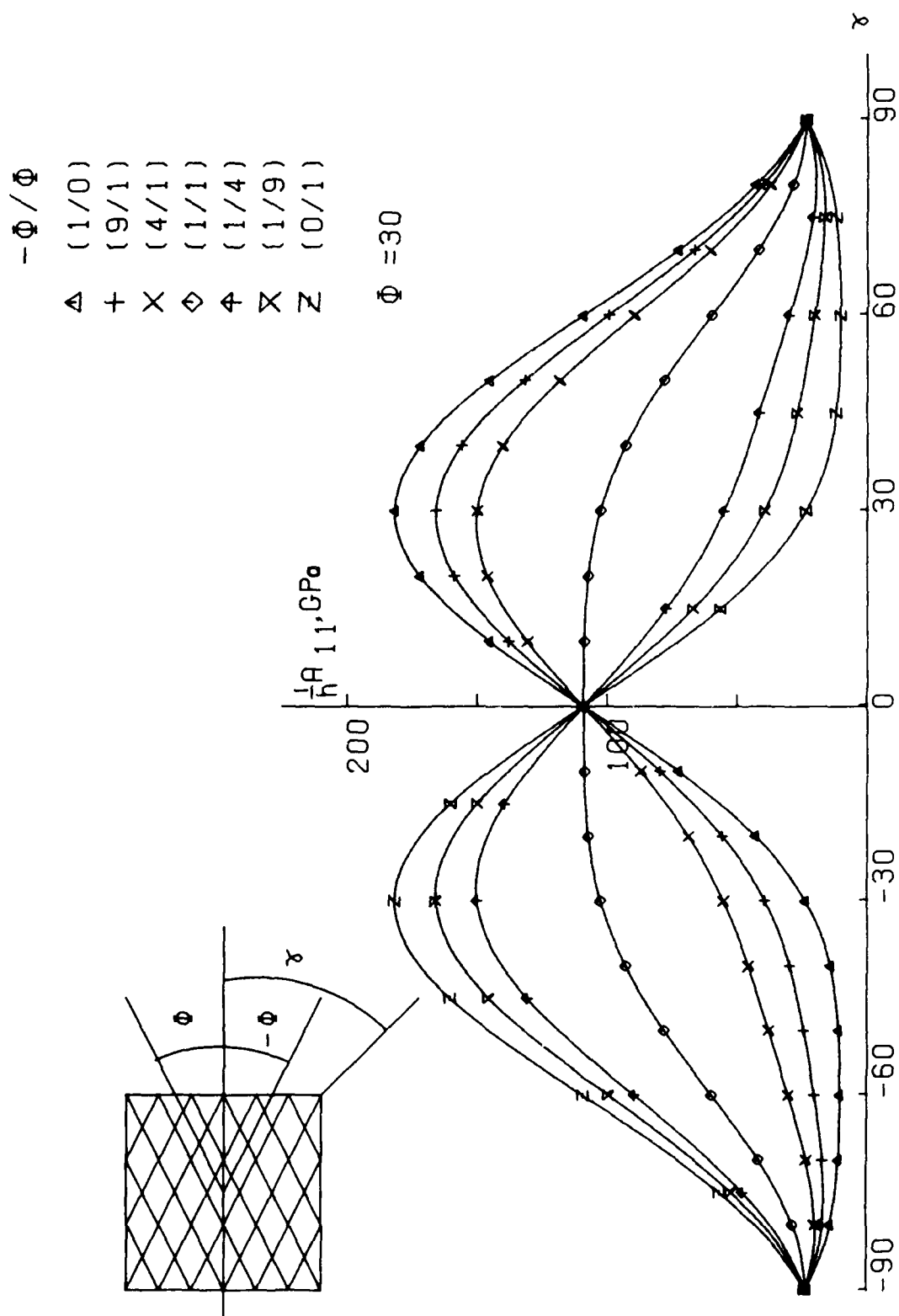


FIG.:13

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 \square (0/1)

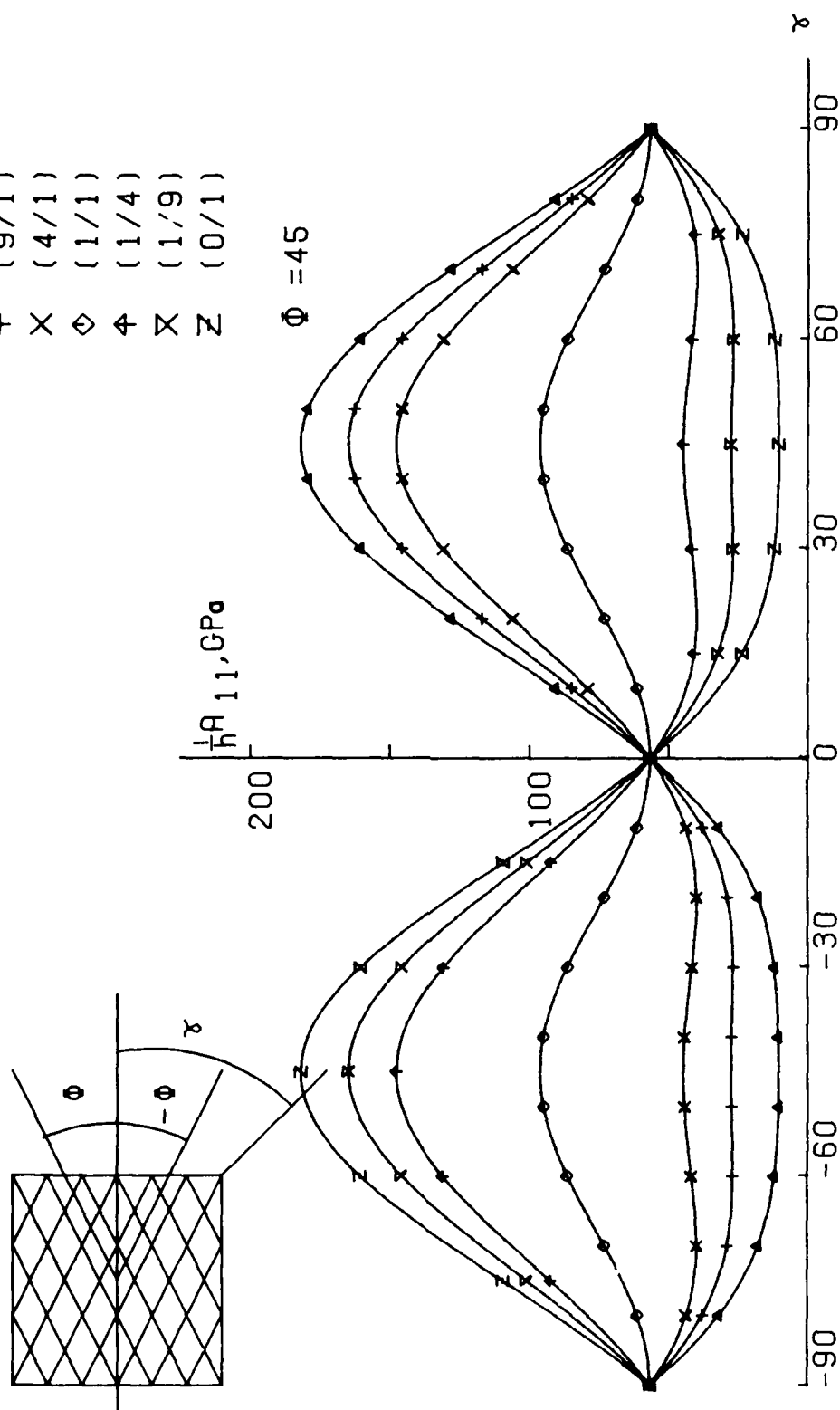
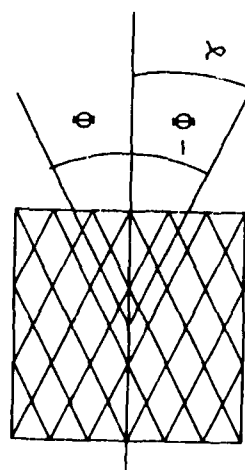


FIG.:14

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 \square (0/1)



$\frac{1}{h}A_{11}, \text{GPa}$

$\Phi = 60$

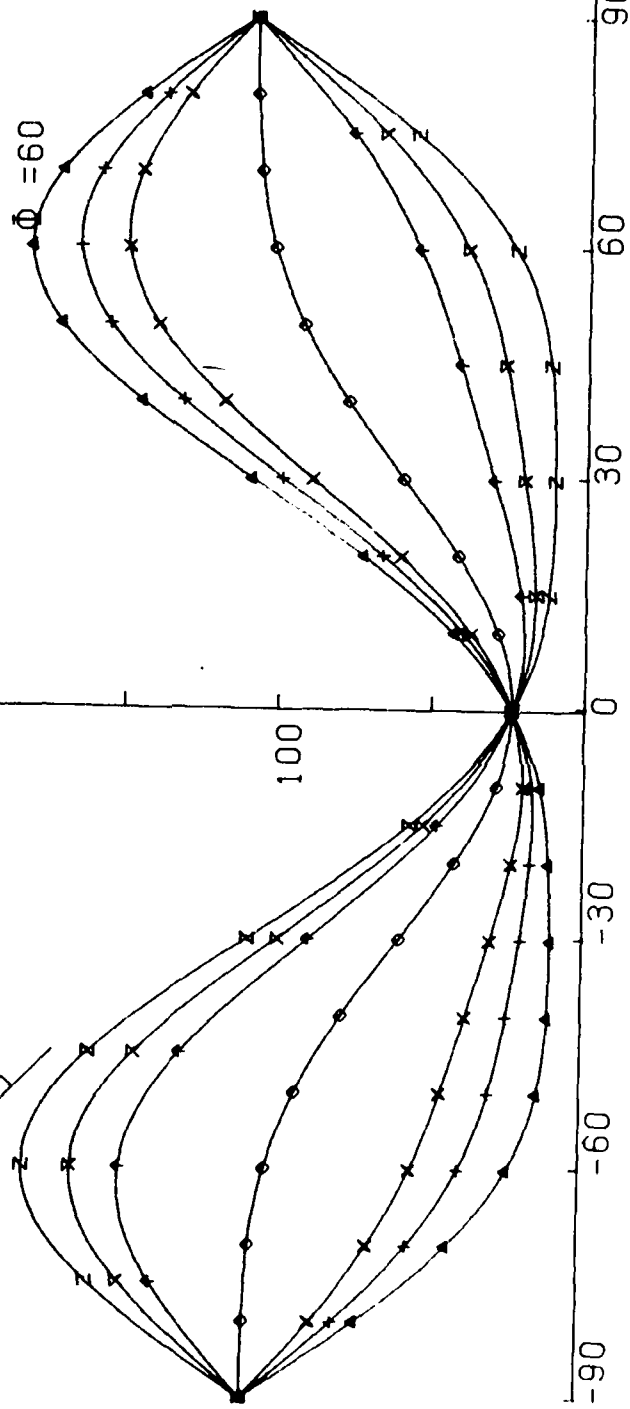


FIG.:15

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 Σ (0/1)

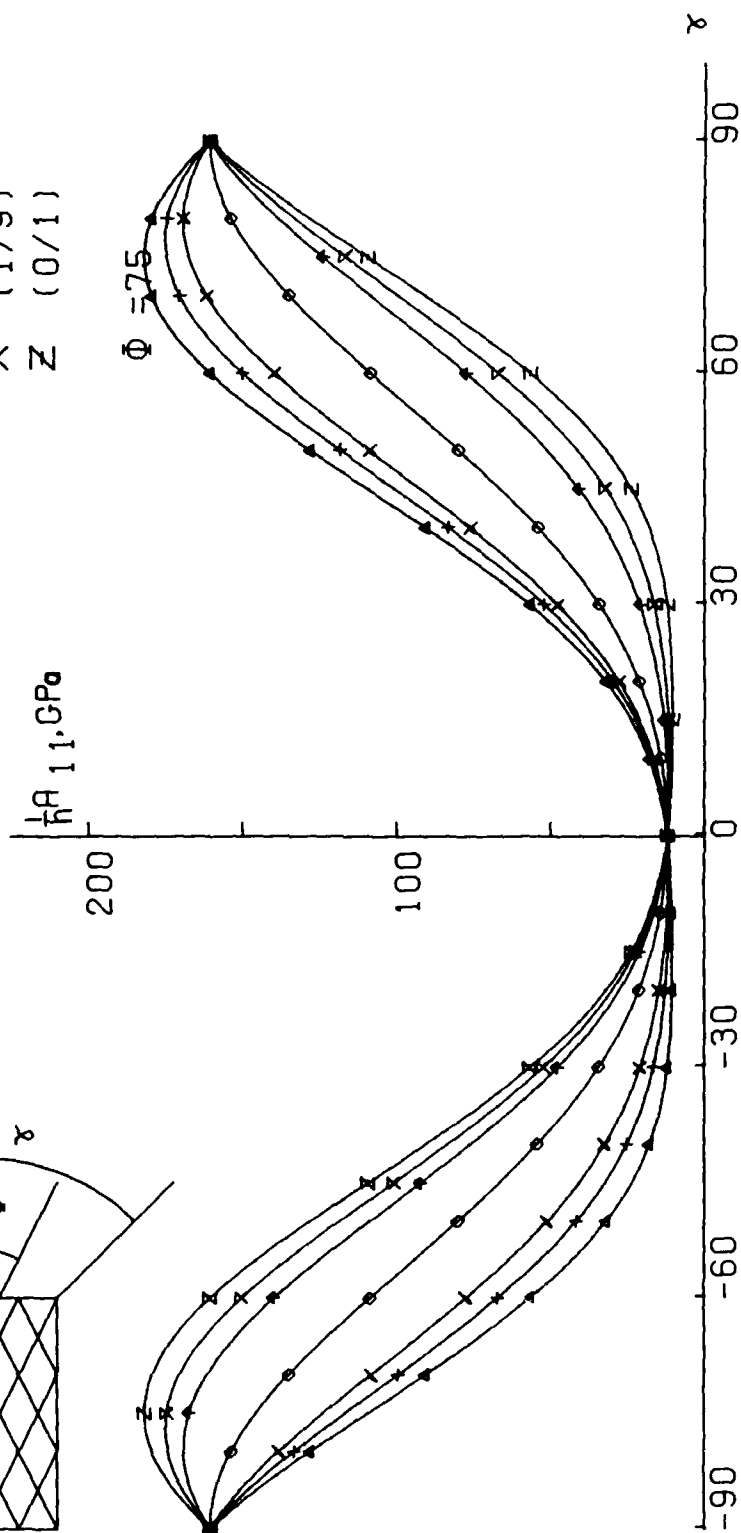
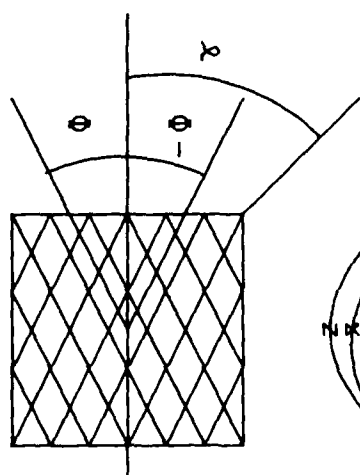


FIG.:16

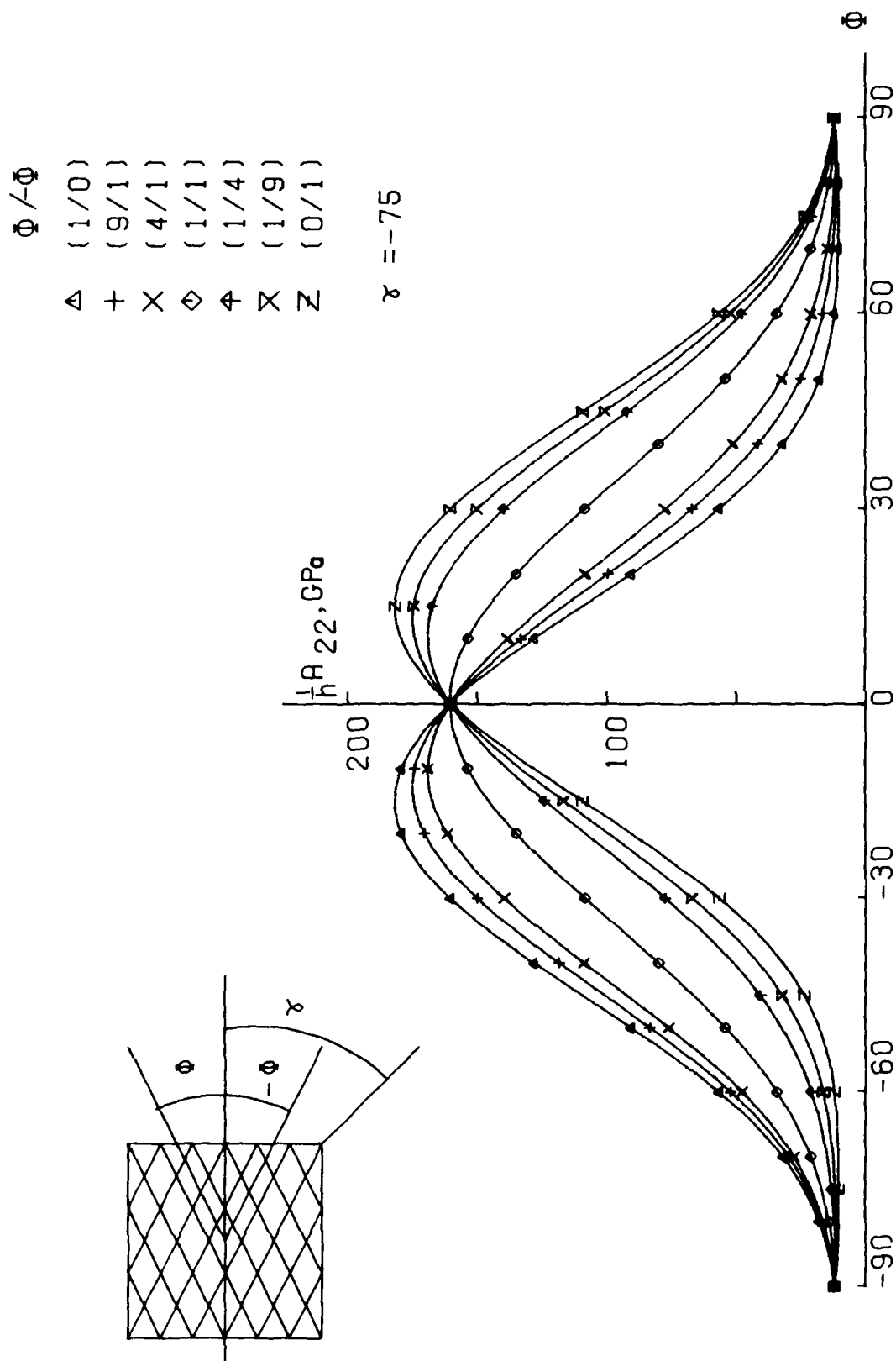


FIG.:17

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = -60$

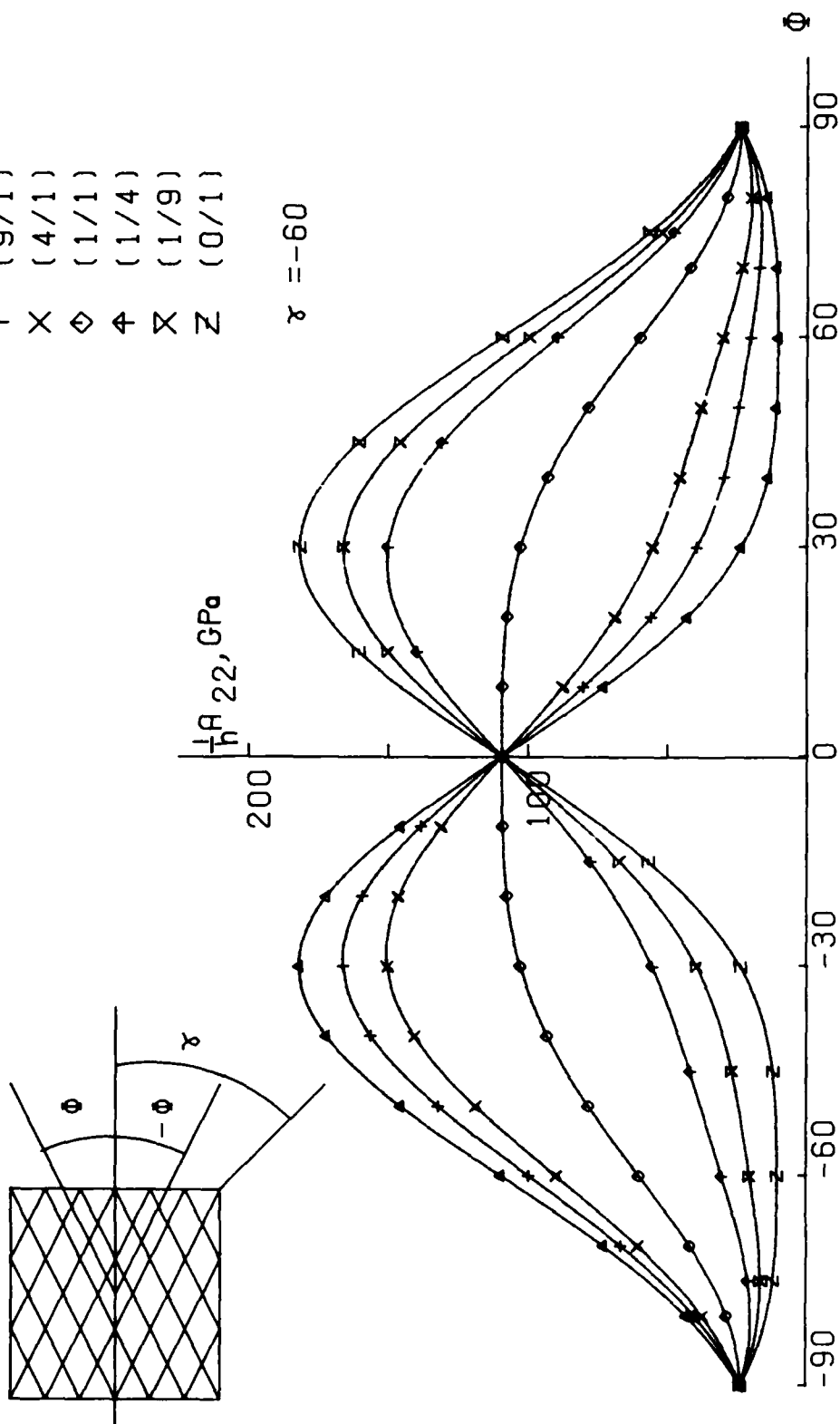


FIG.:18

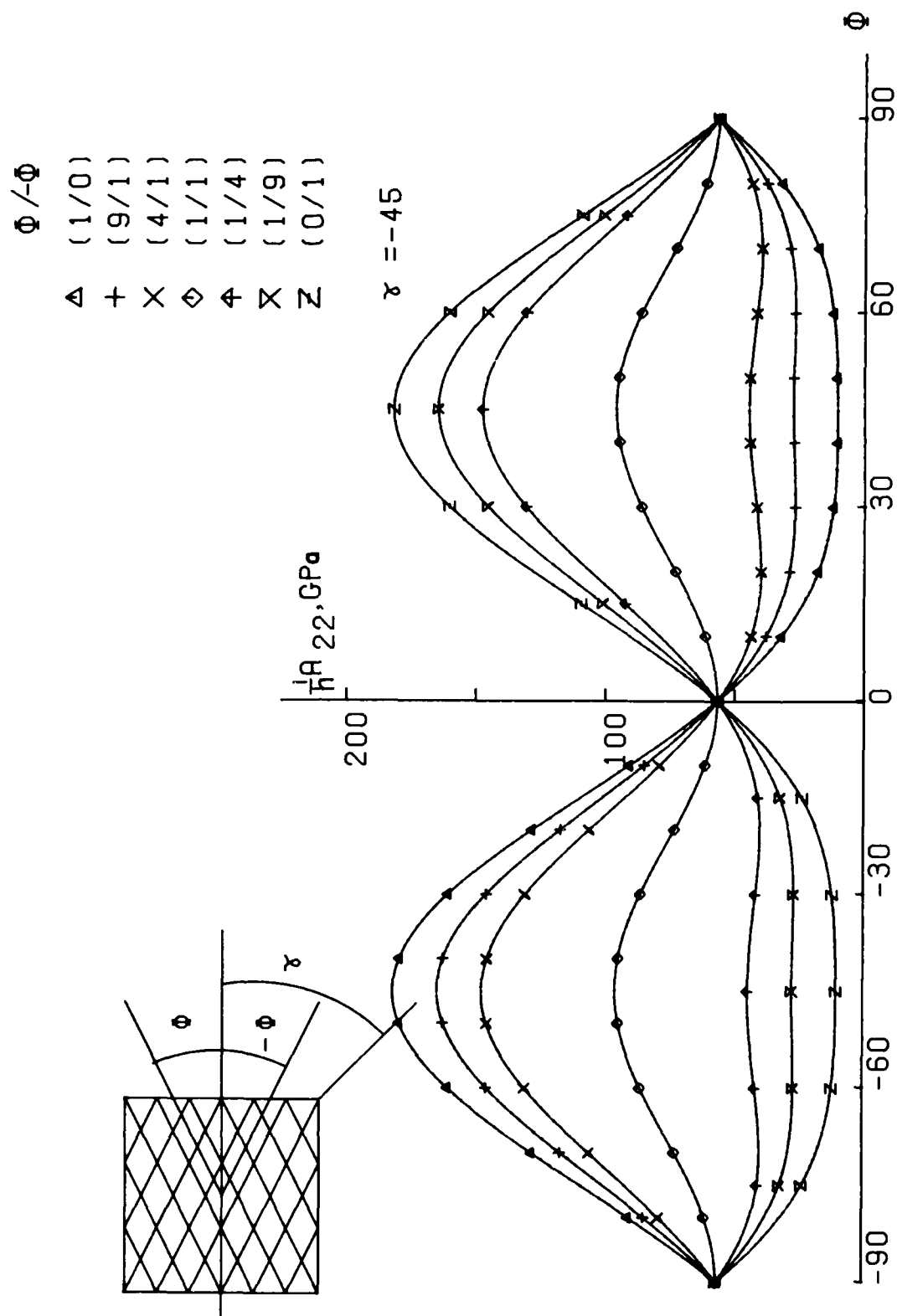


FIG.:19

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

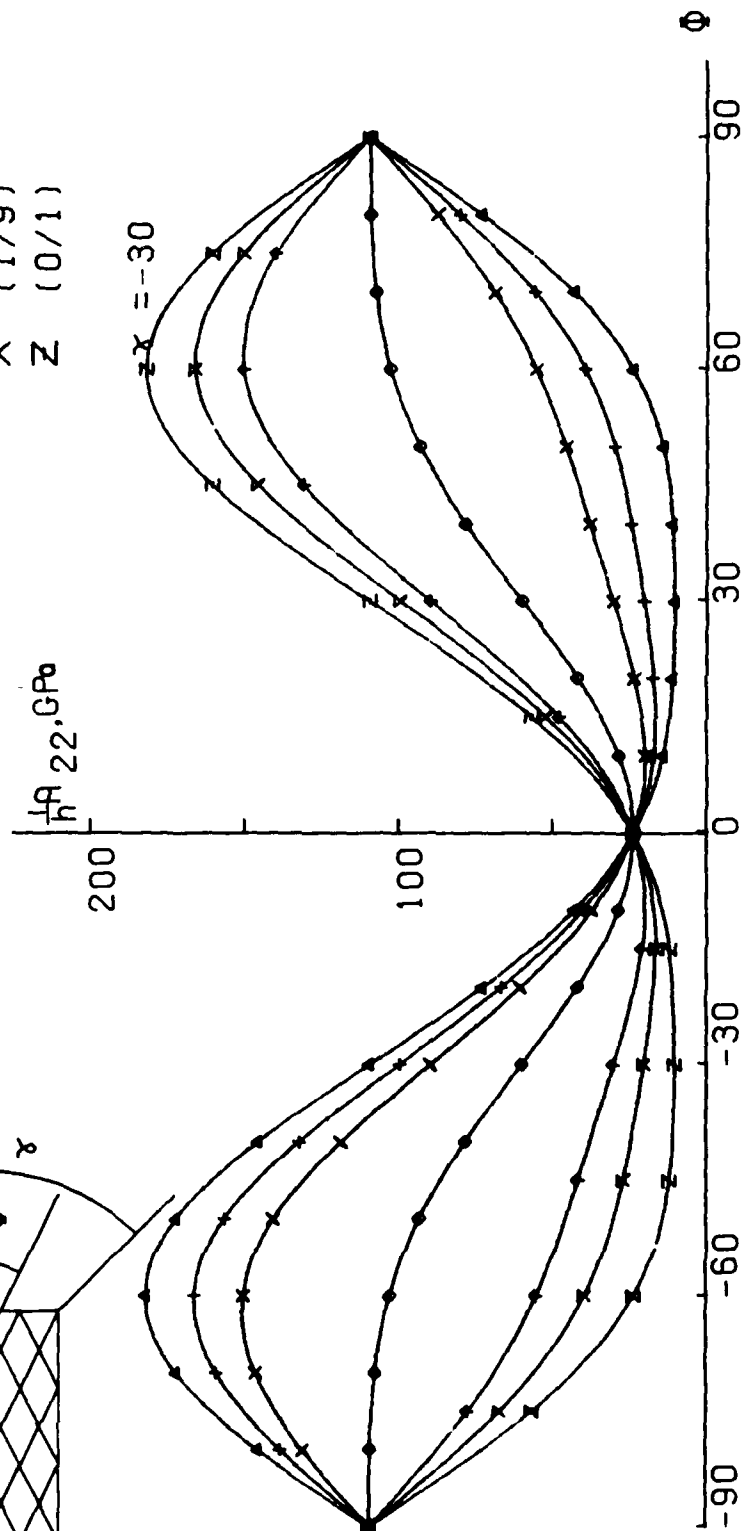
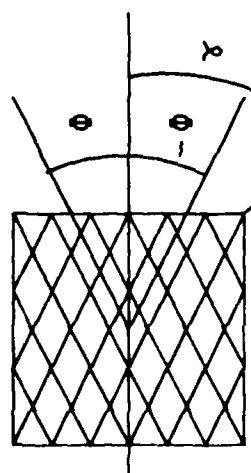


FIG.:20

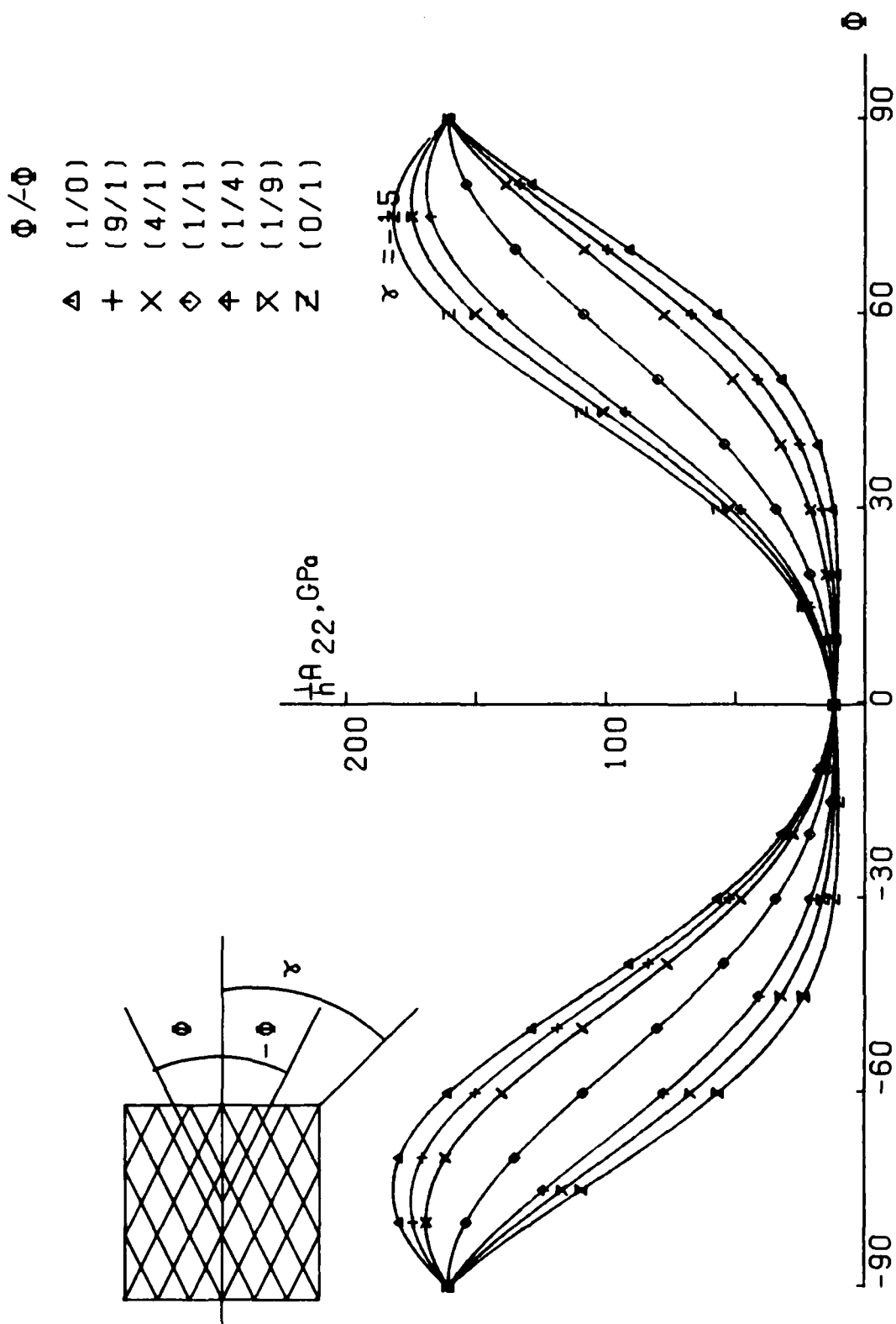


FIG.: 21

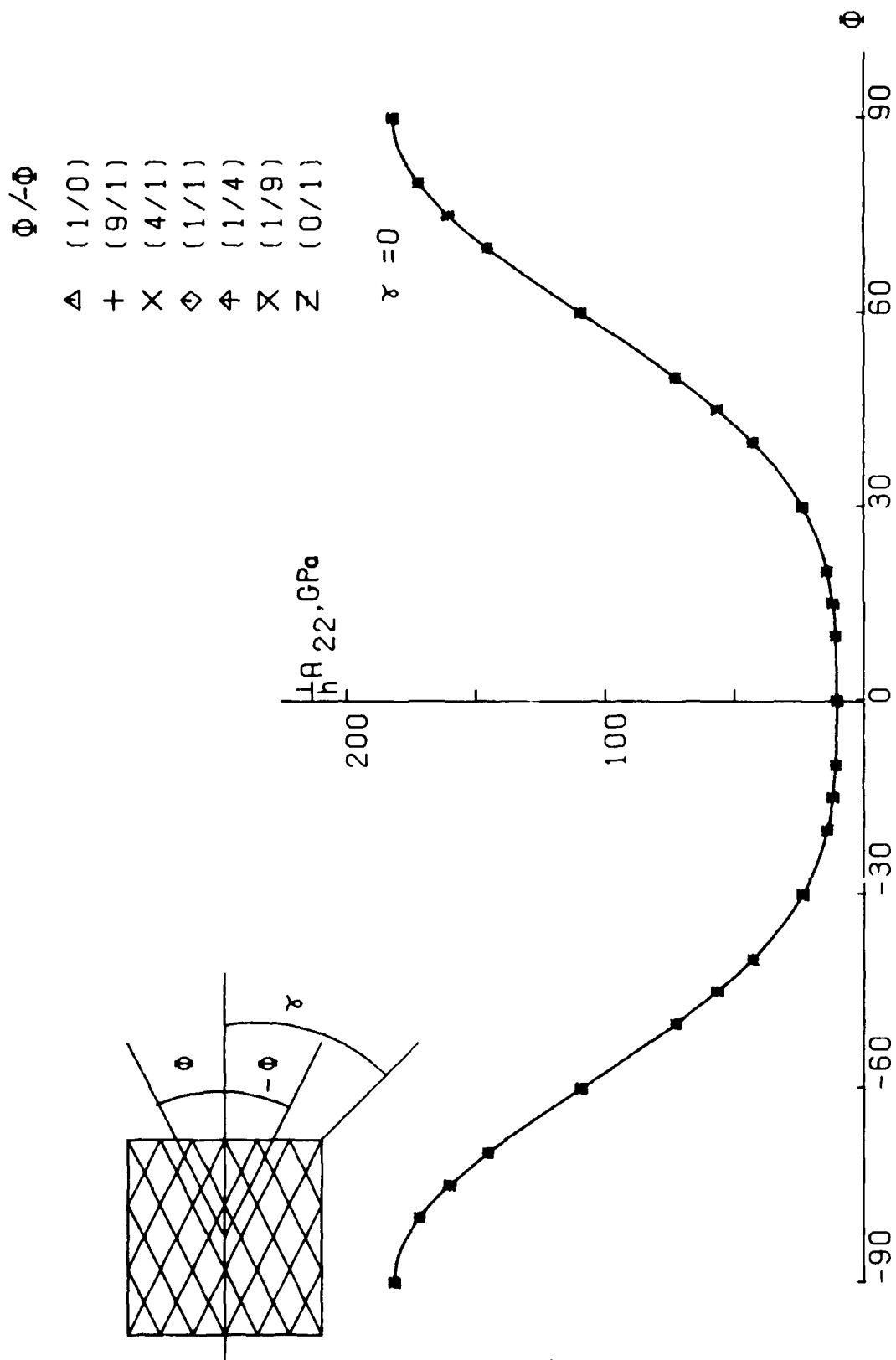


FIG.:22

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 \times (1/9)
 Σ (0/1)

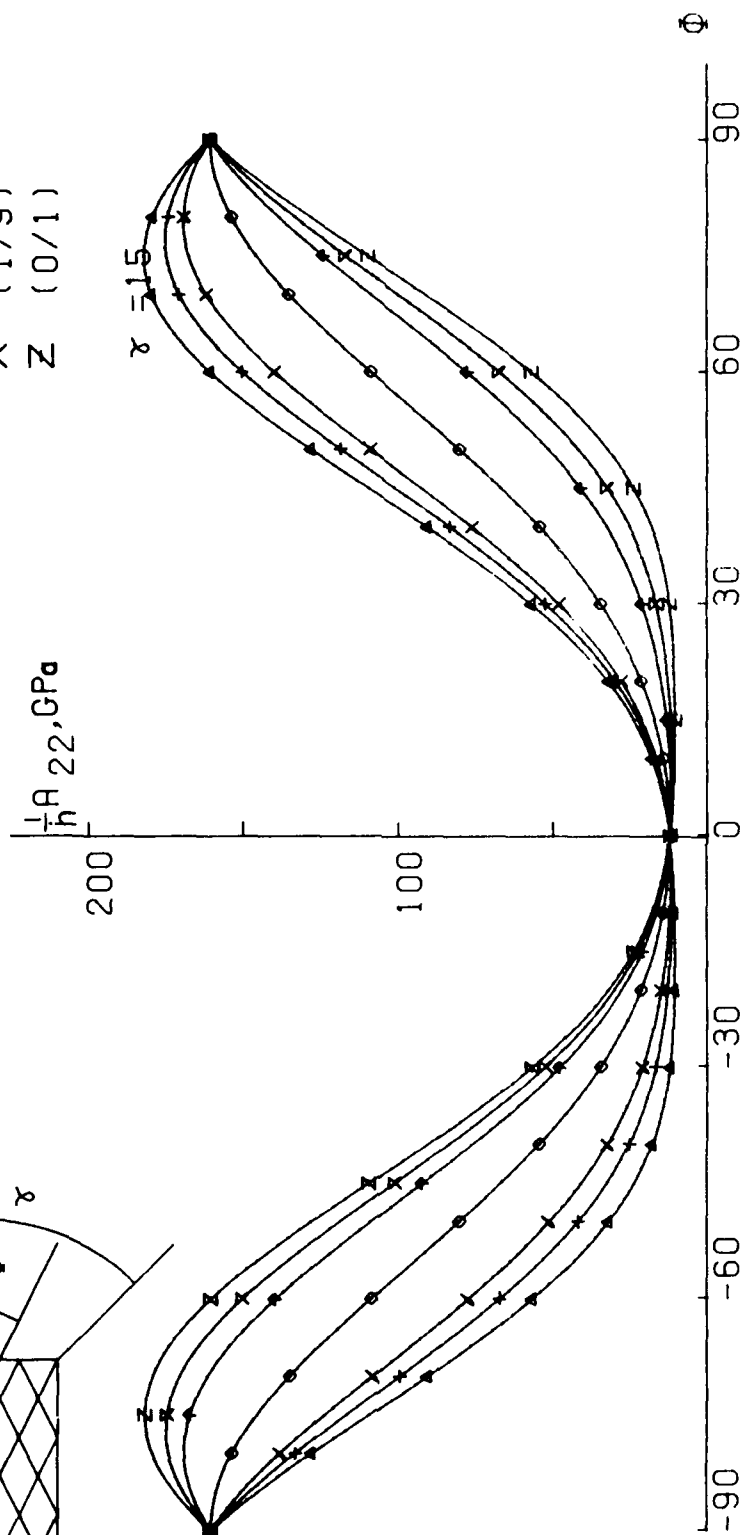
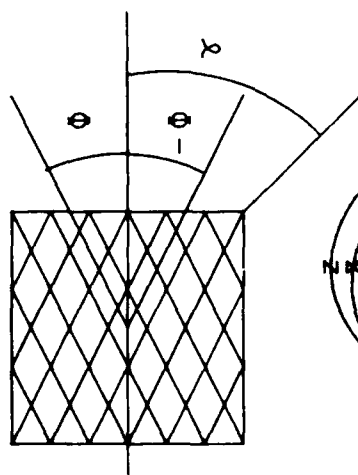


FIG.:23

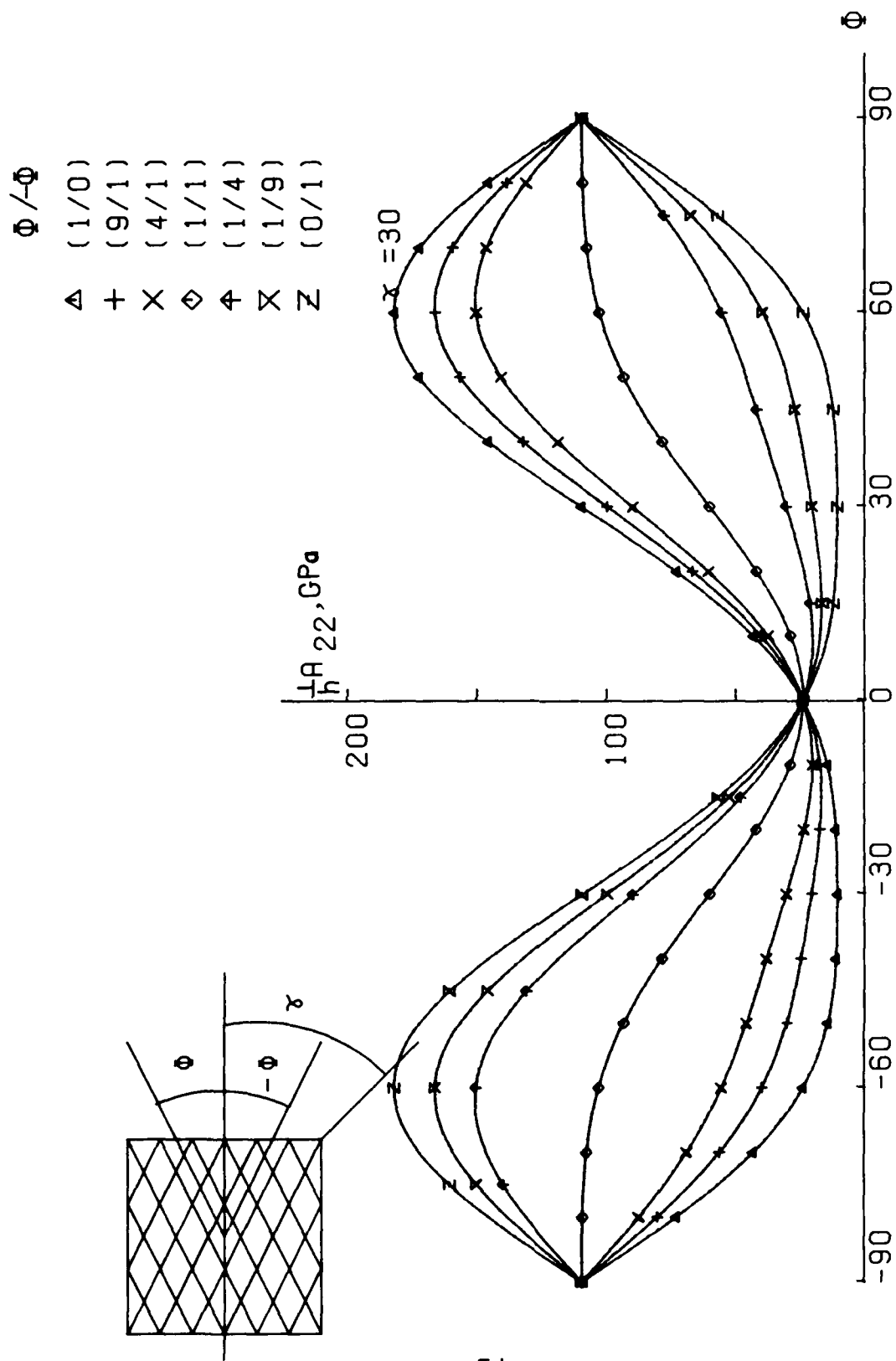


FIG.:24

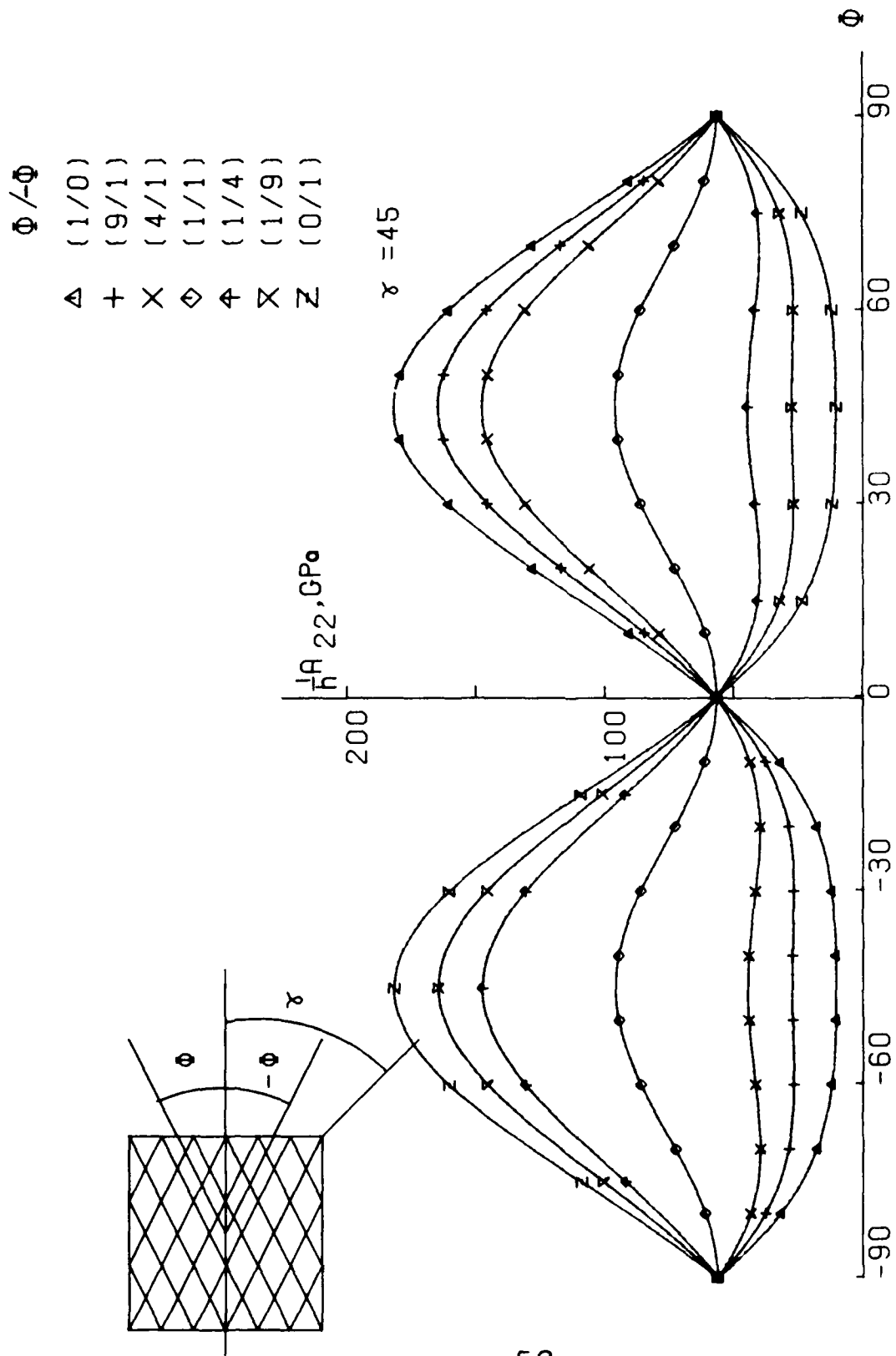


FIG.: 25

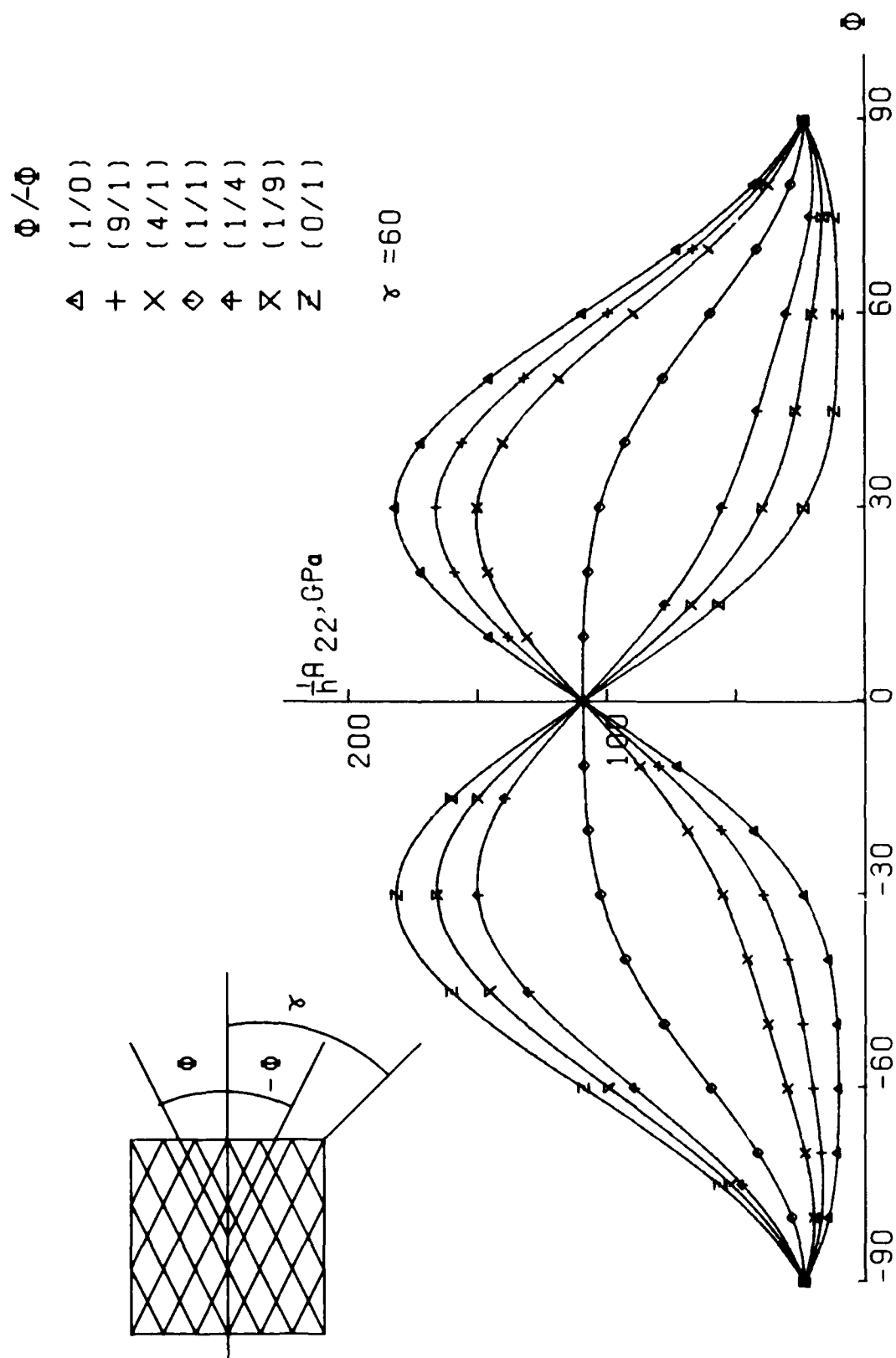


FIG.: 26

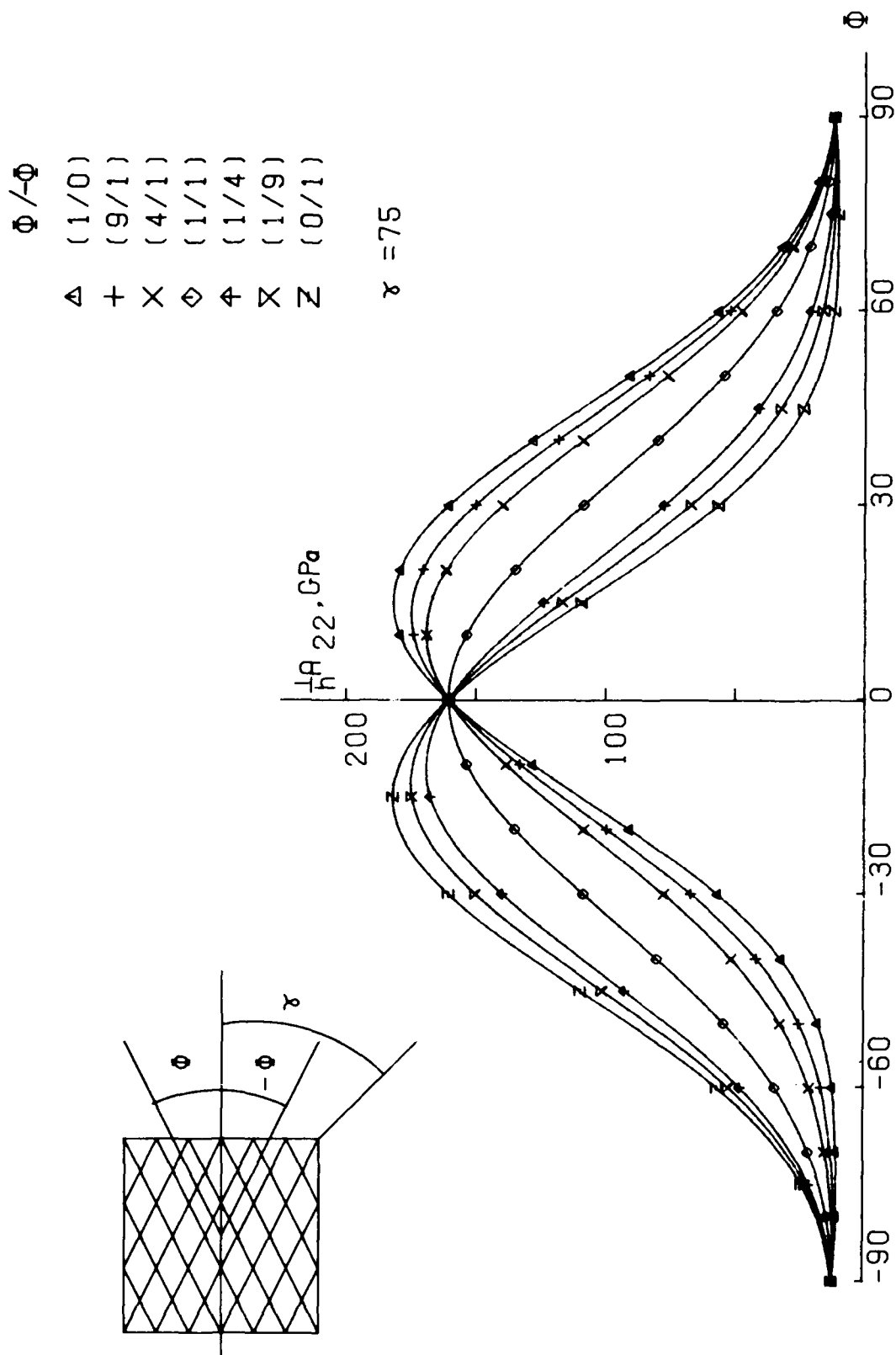


FIG.: 27

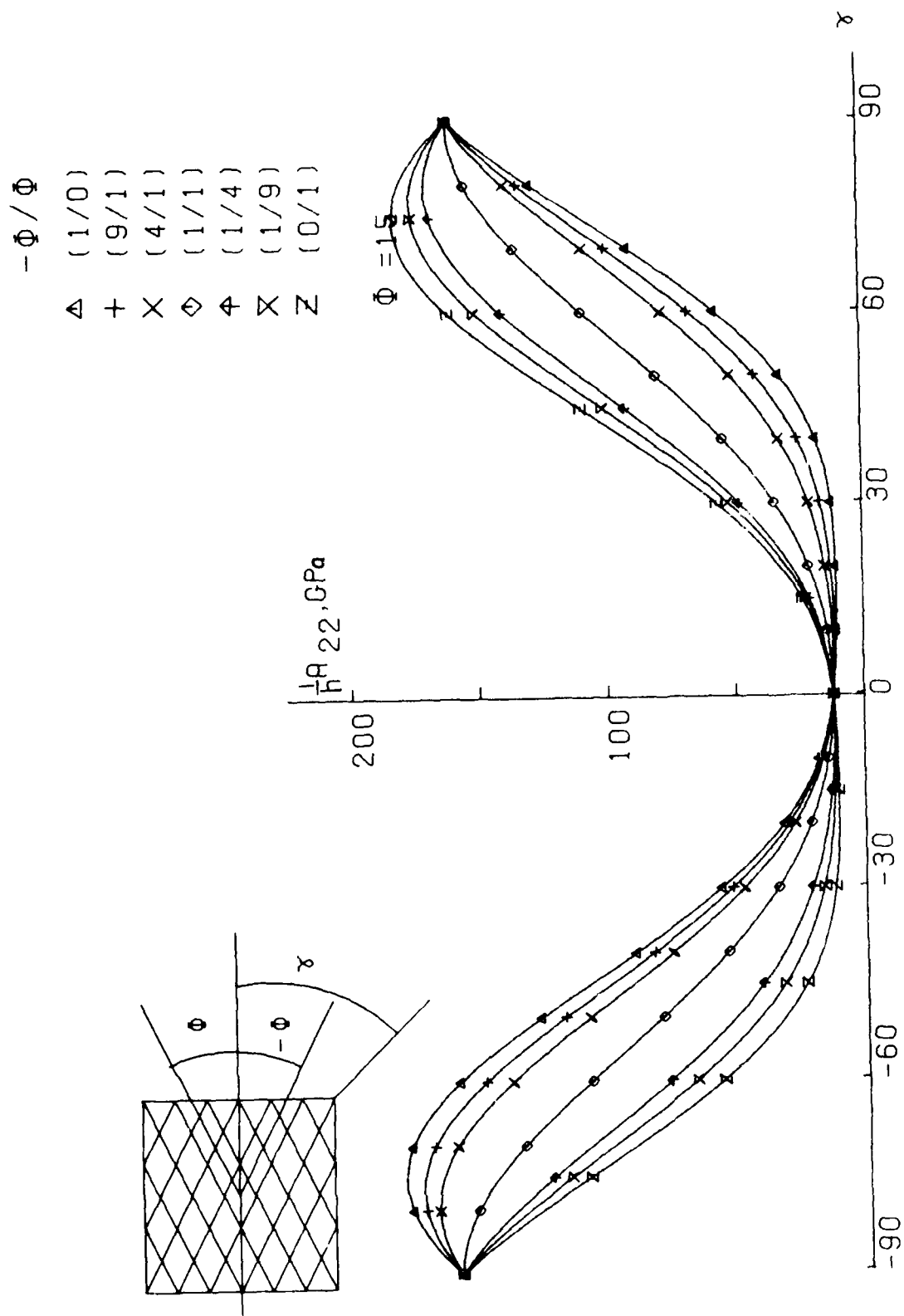


FIG.:28

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

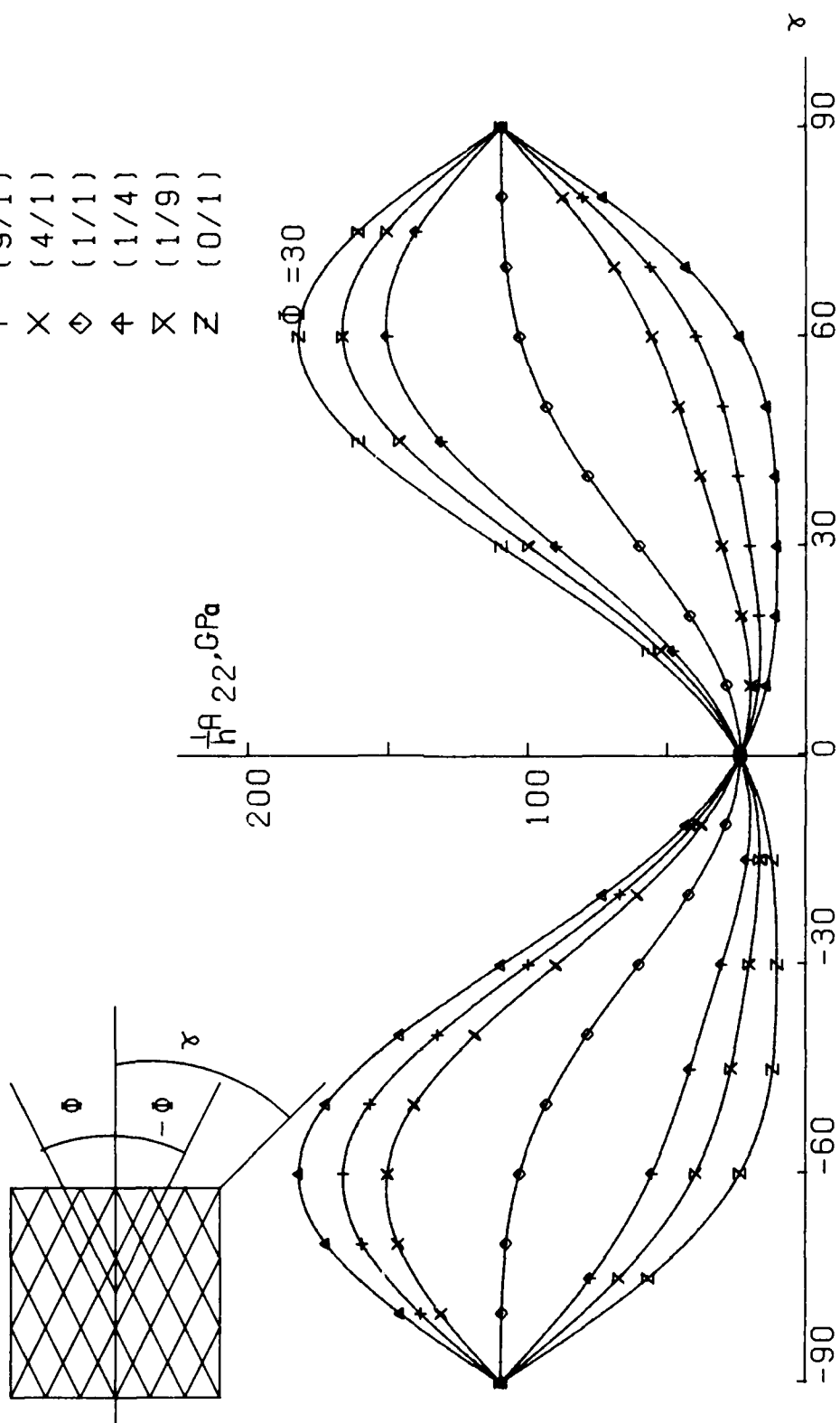


FIG.:29

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

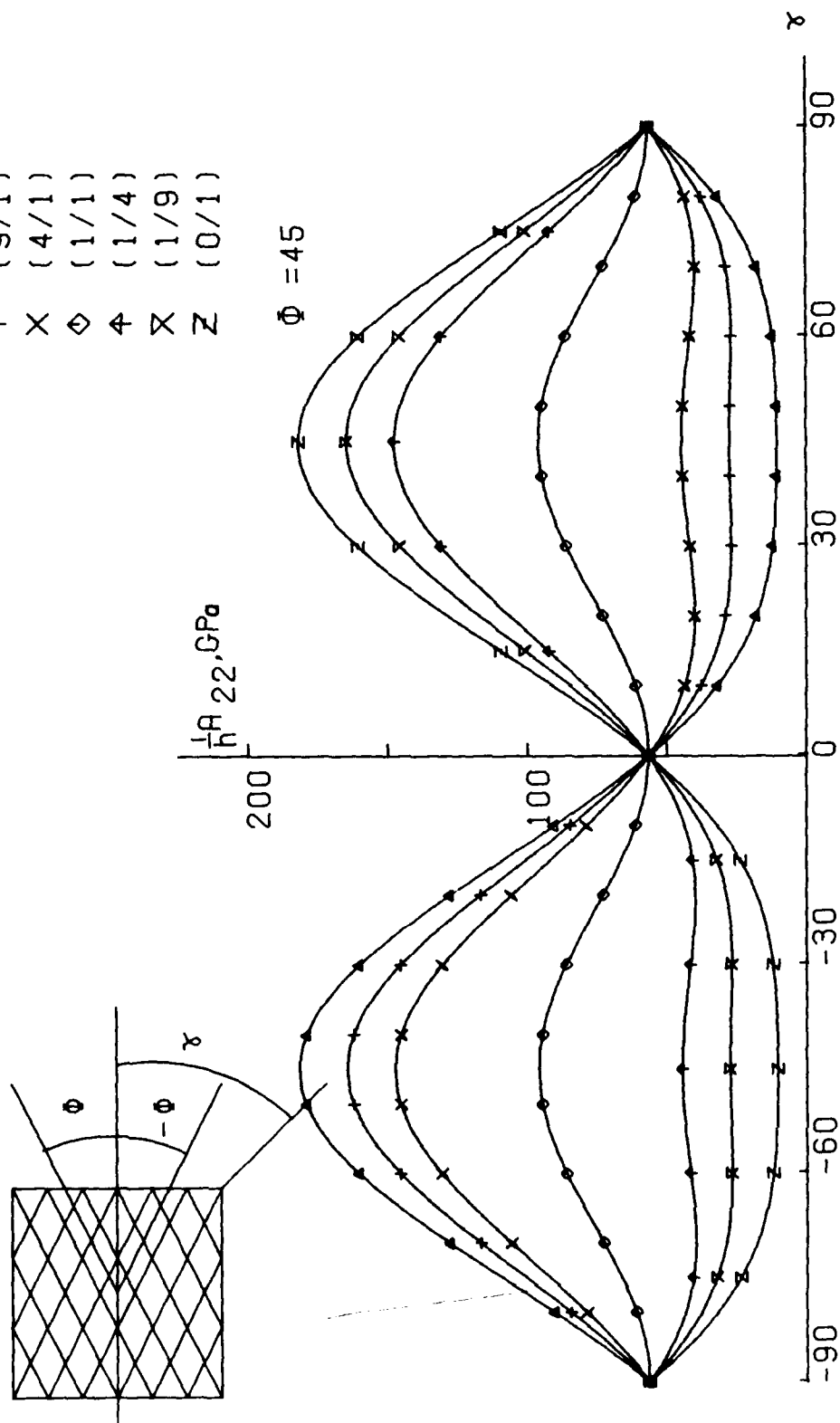


FIG.: 30

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 \square (0/1)

$\Phi = 60$

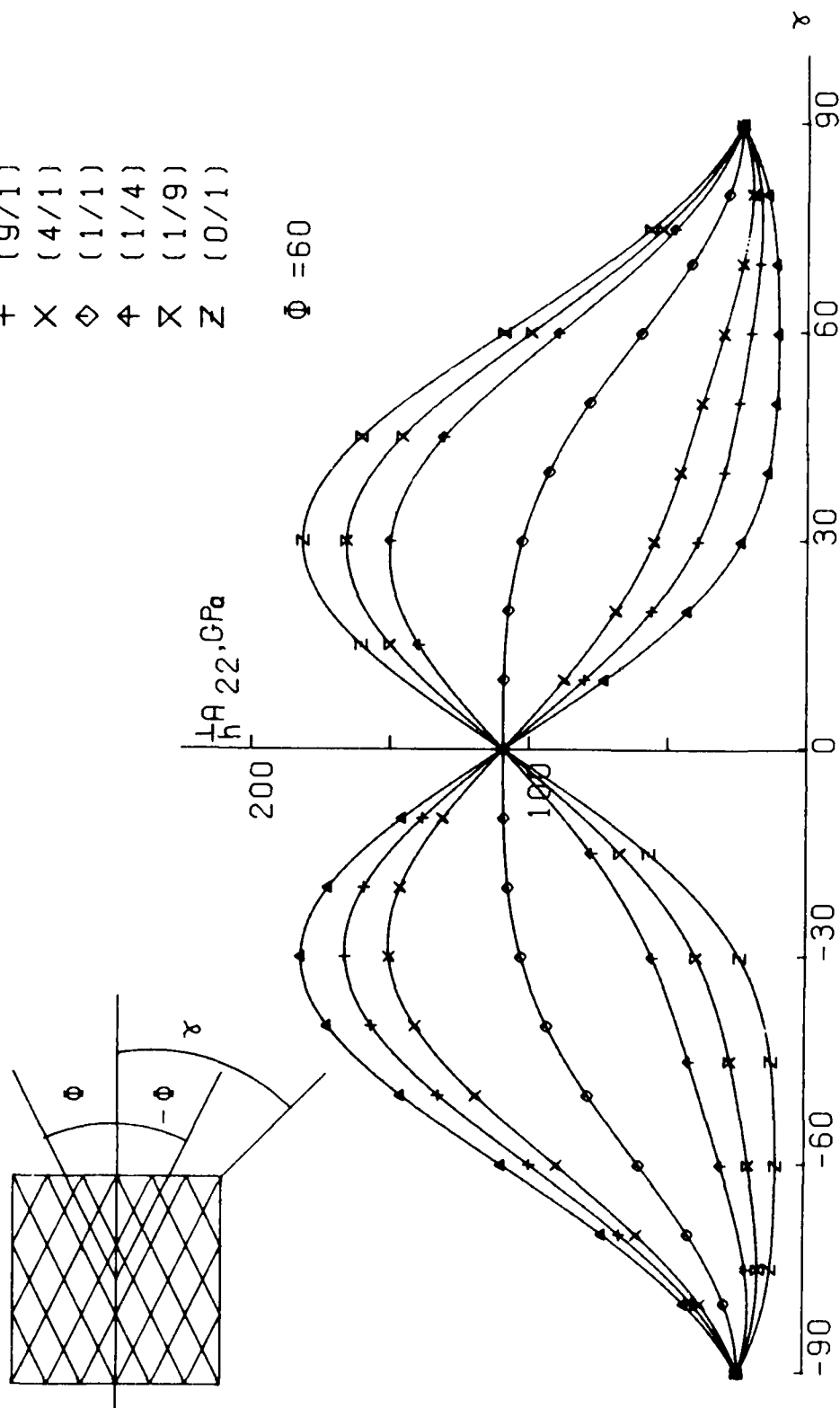


FIG.:31

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ϕ (1/4)
 \times (1/9)
 Σ (0/1)

$\Phi = 75$

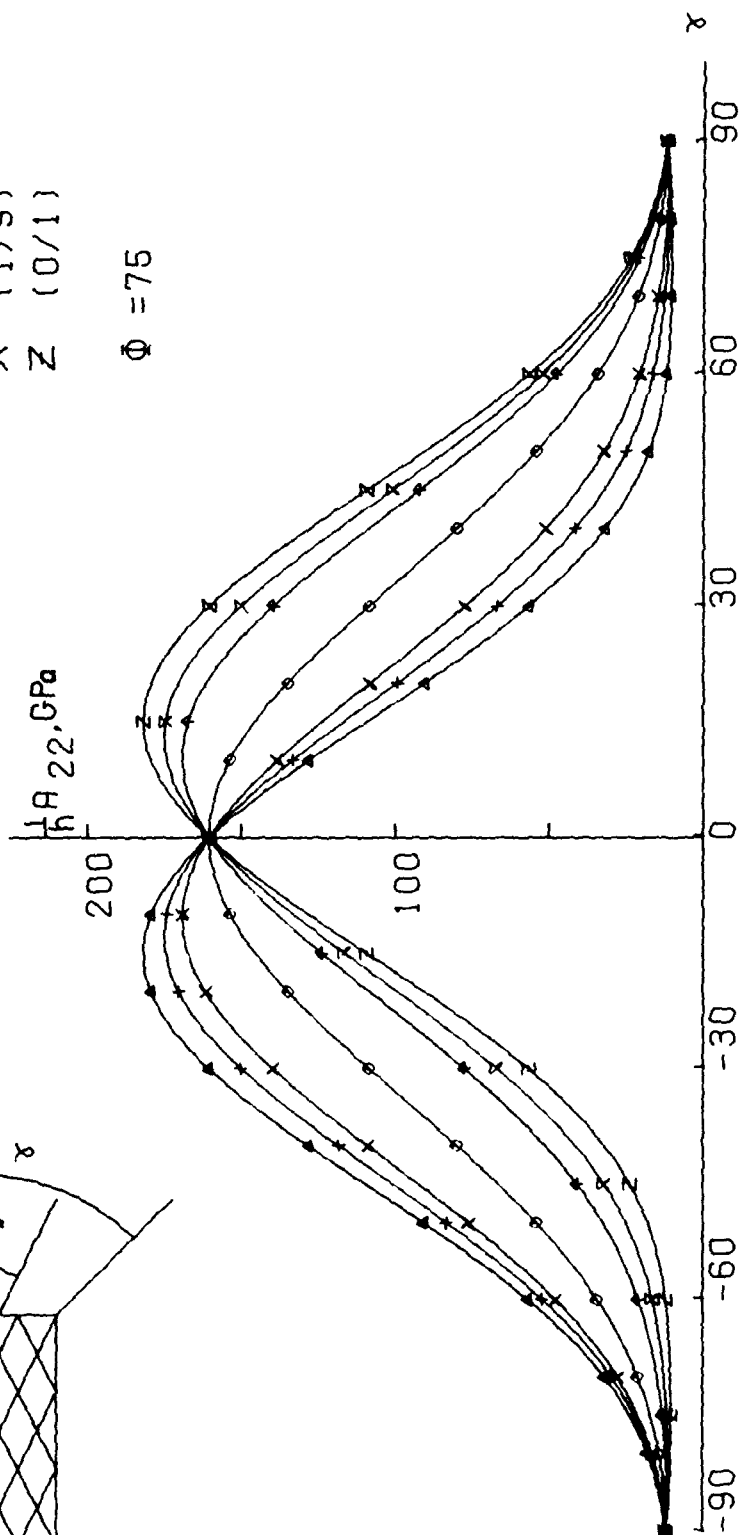
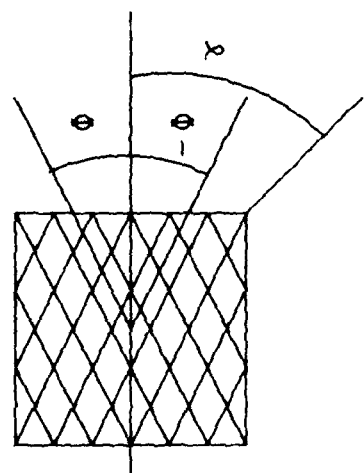


FIG.:32

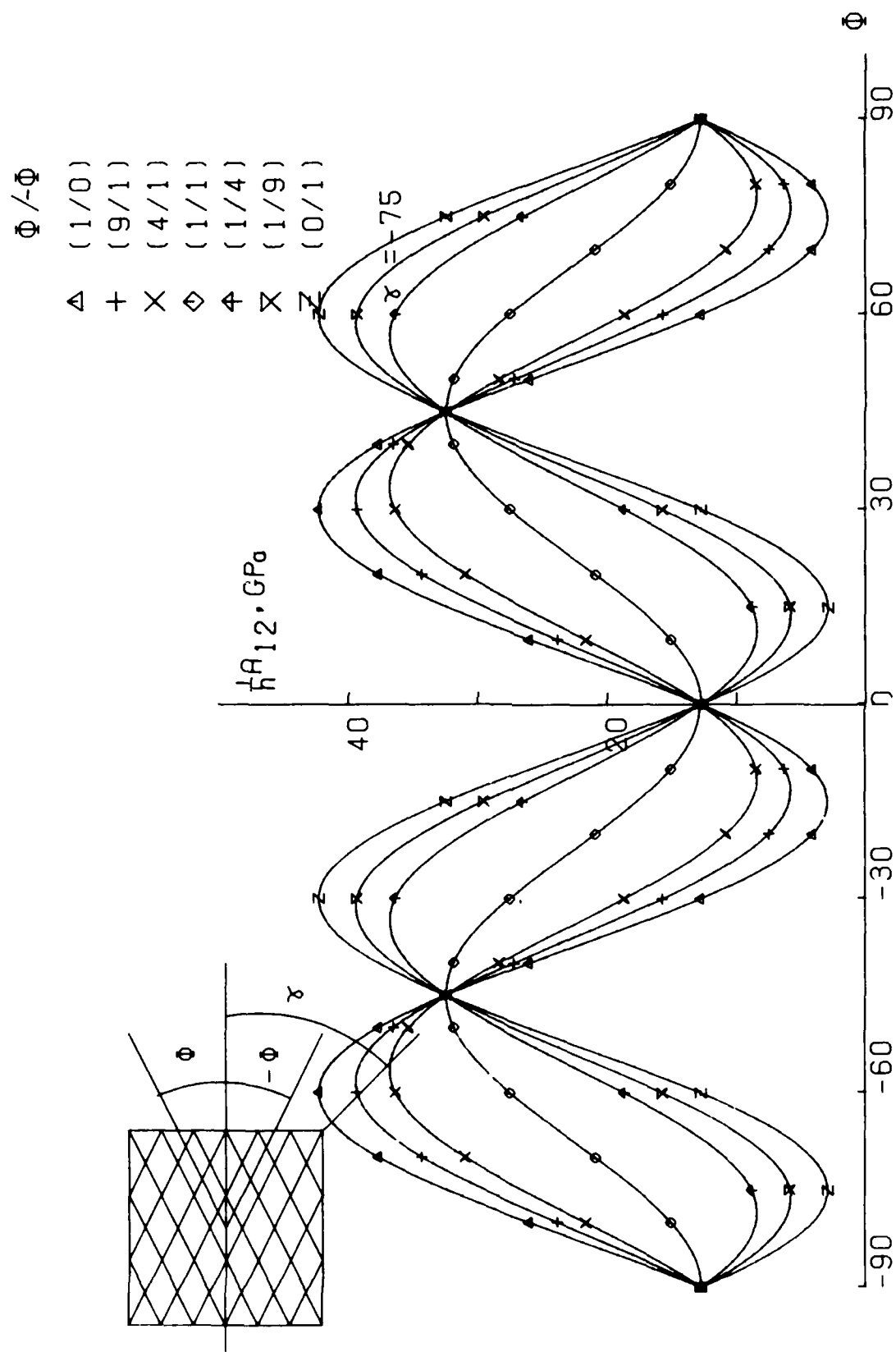


FIG.:33

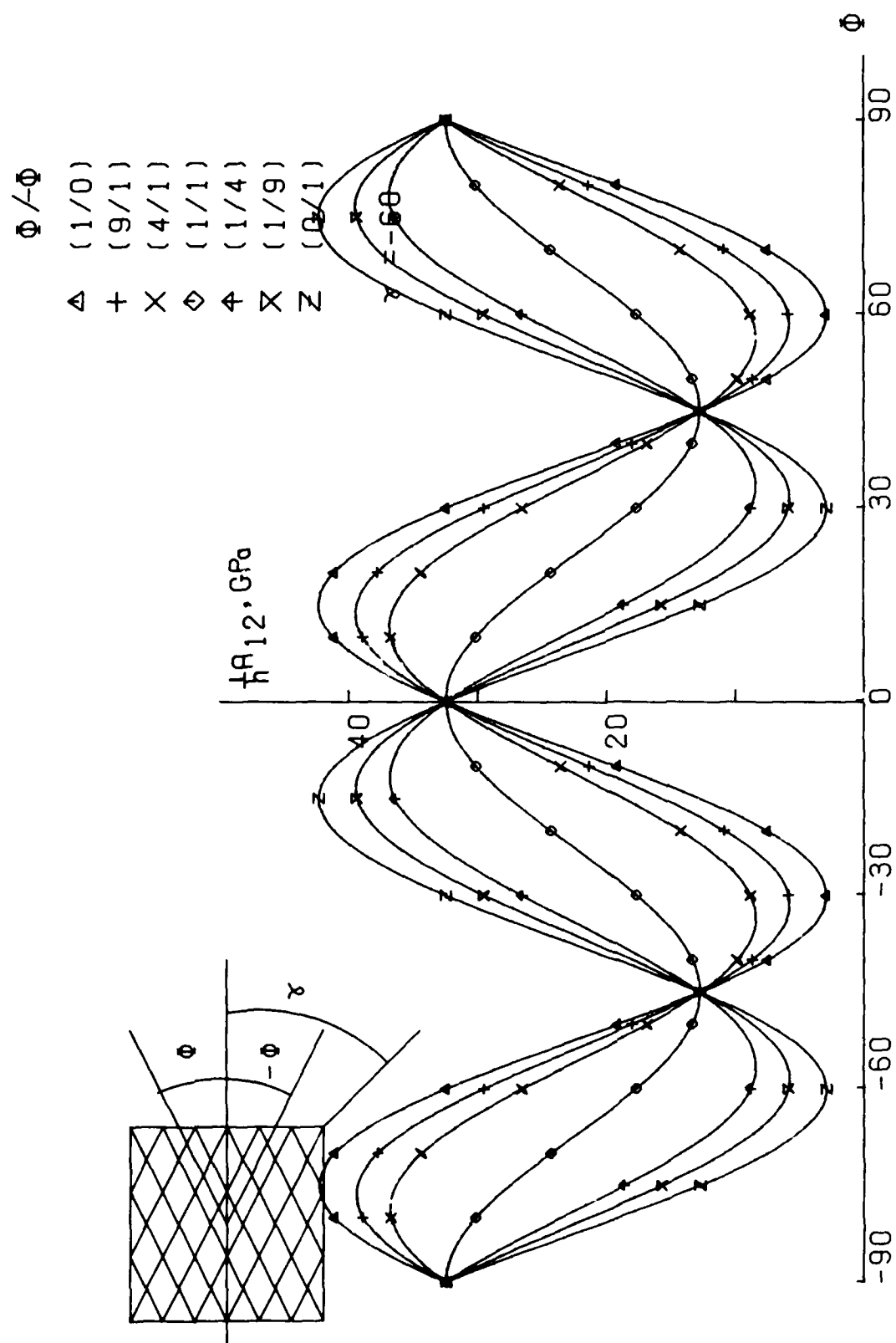


FIG.: 34

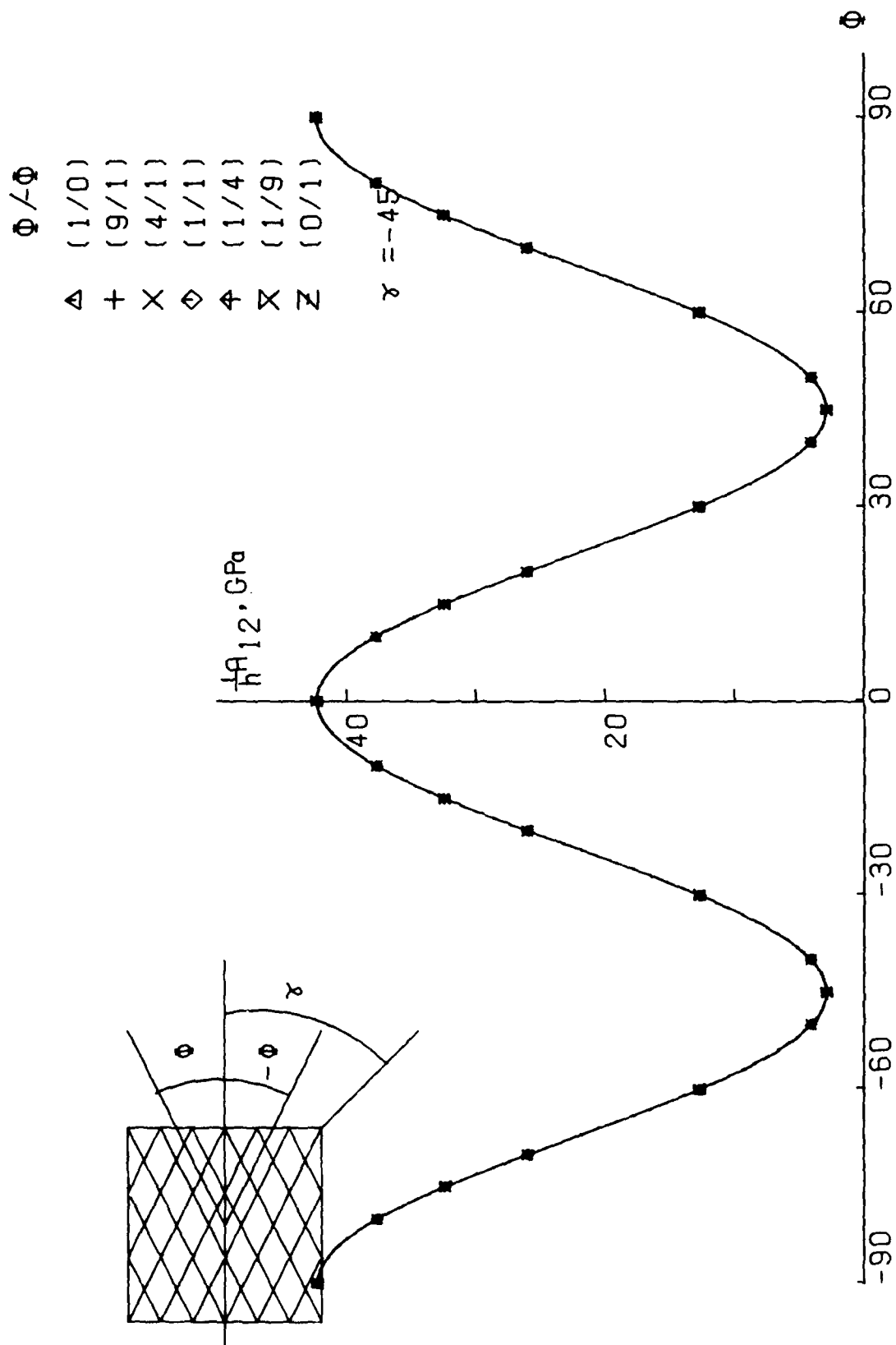


FIG.:35

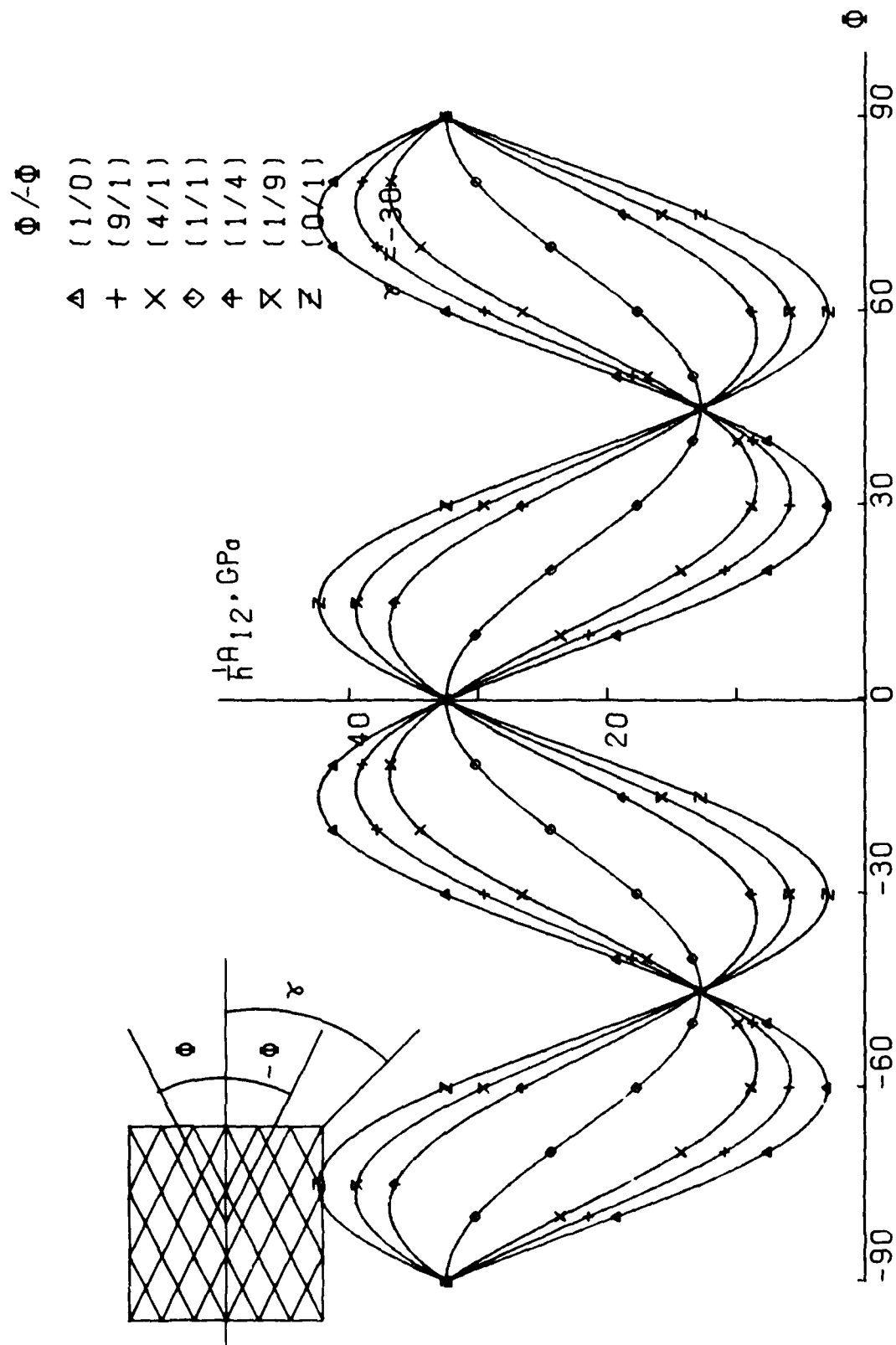


FIG.: 36

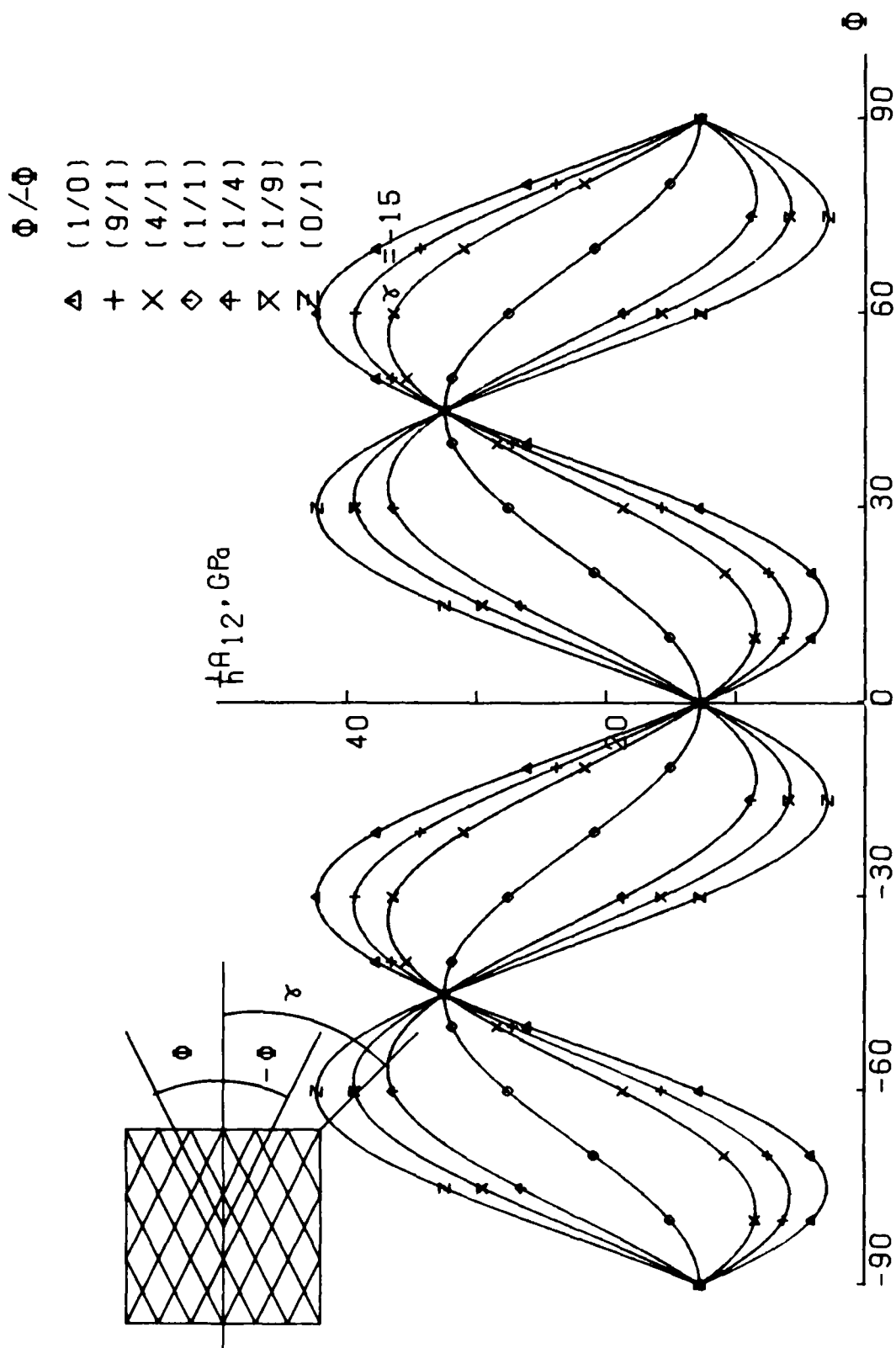


FIG.:37

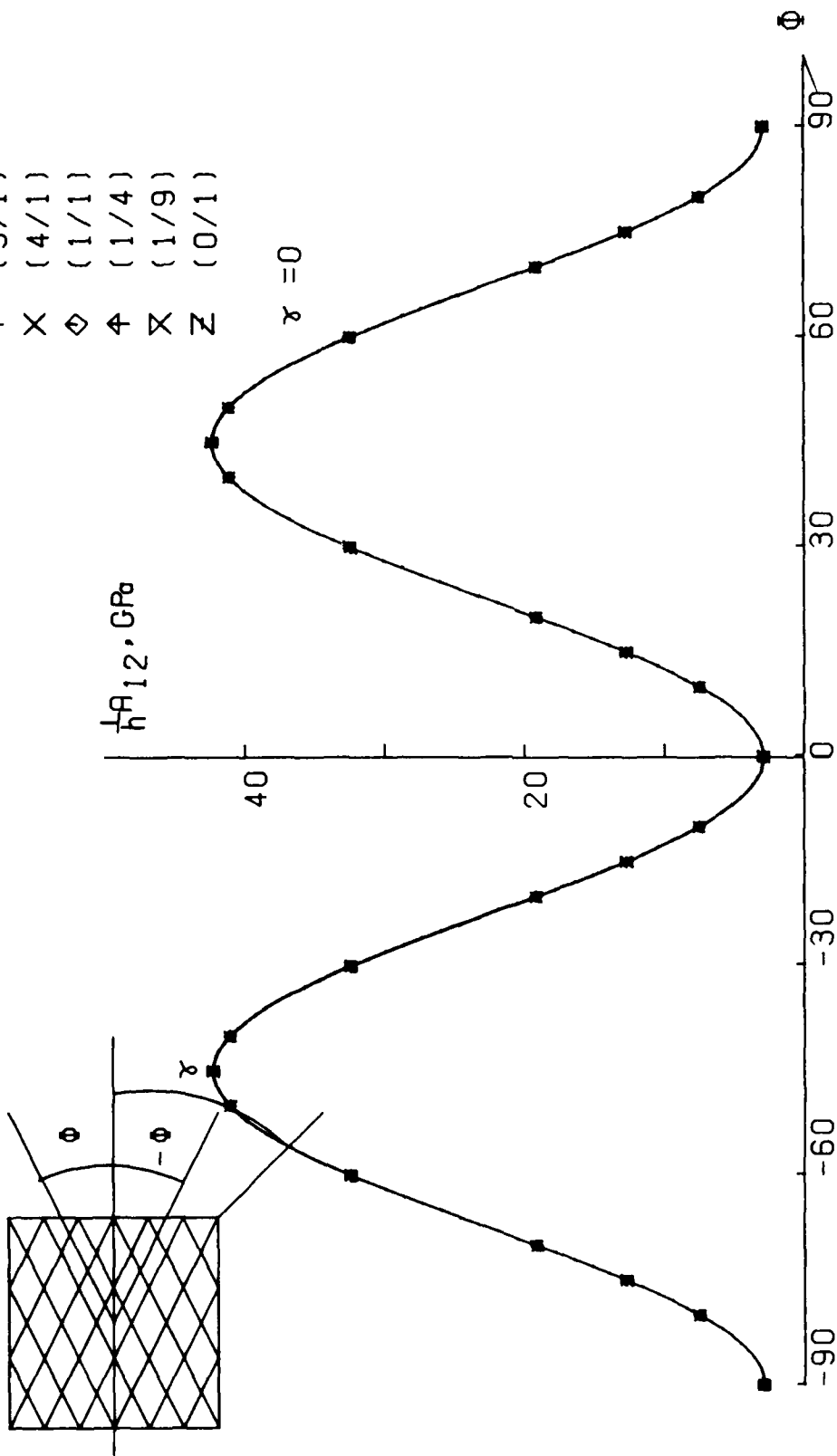


FIG.: 38

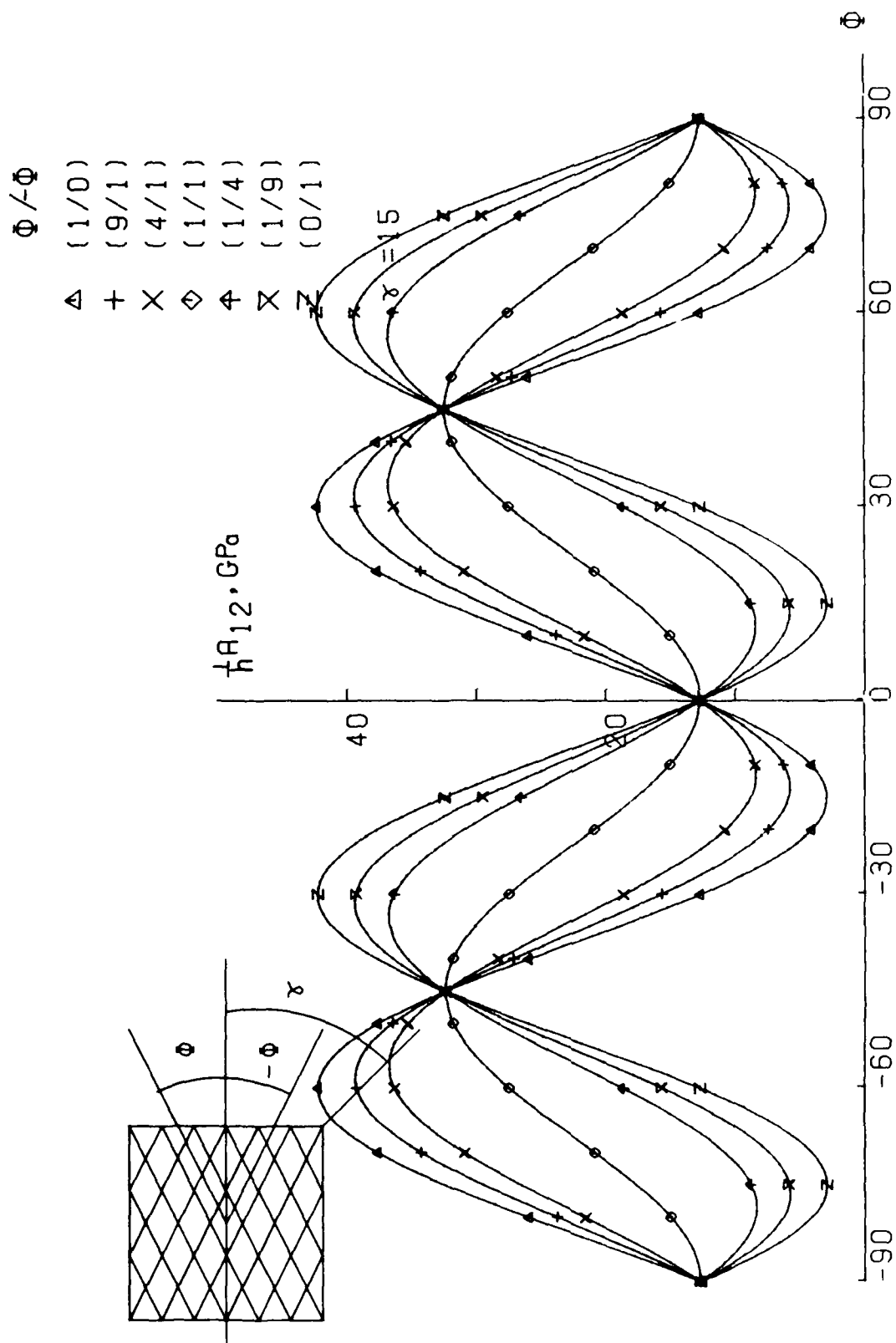


FIG.: 39

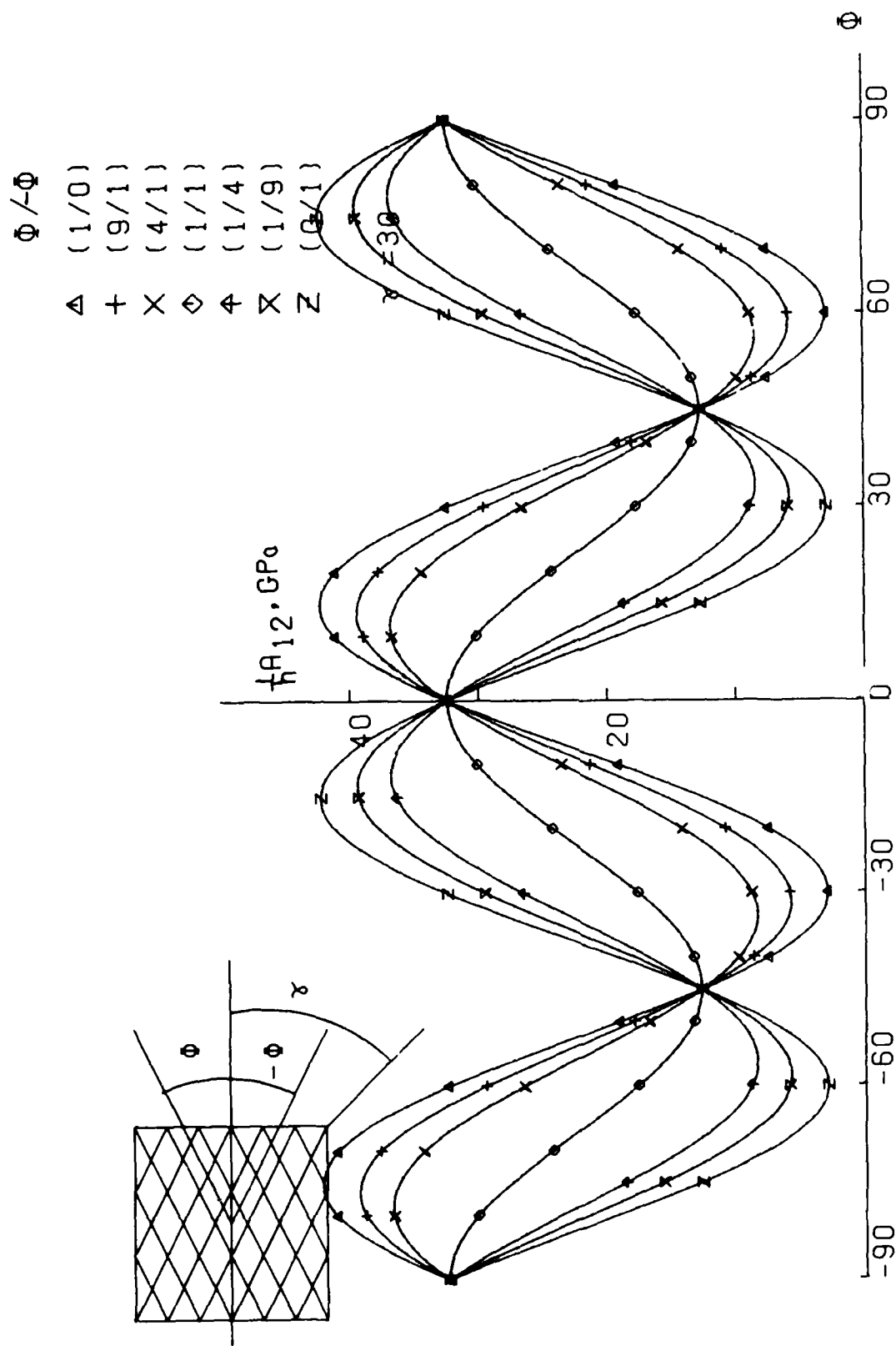


FIG.: 40

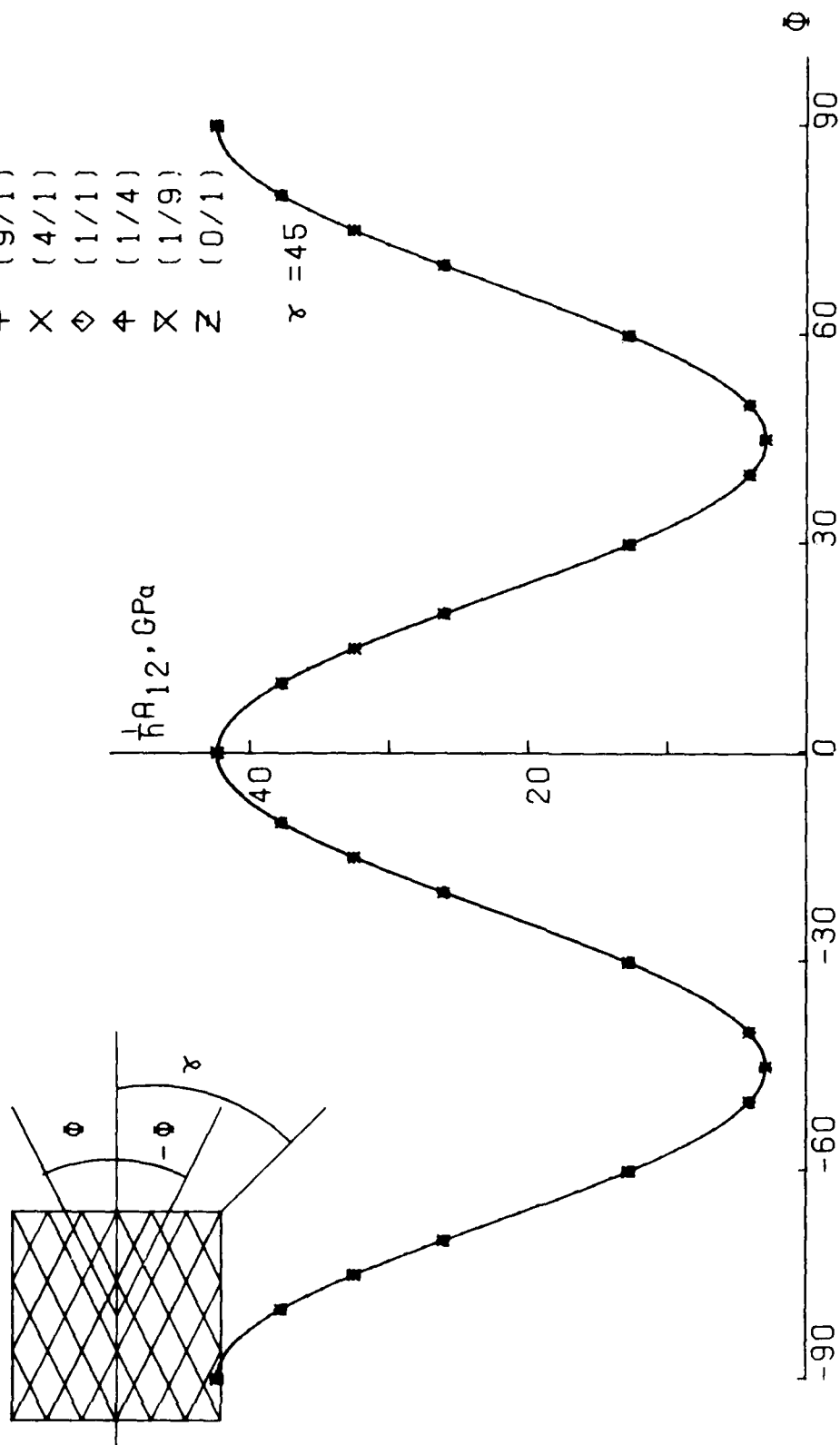


FIG.: 41

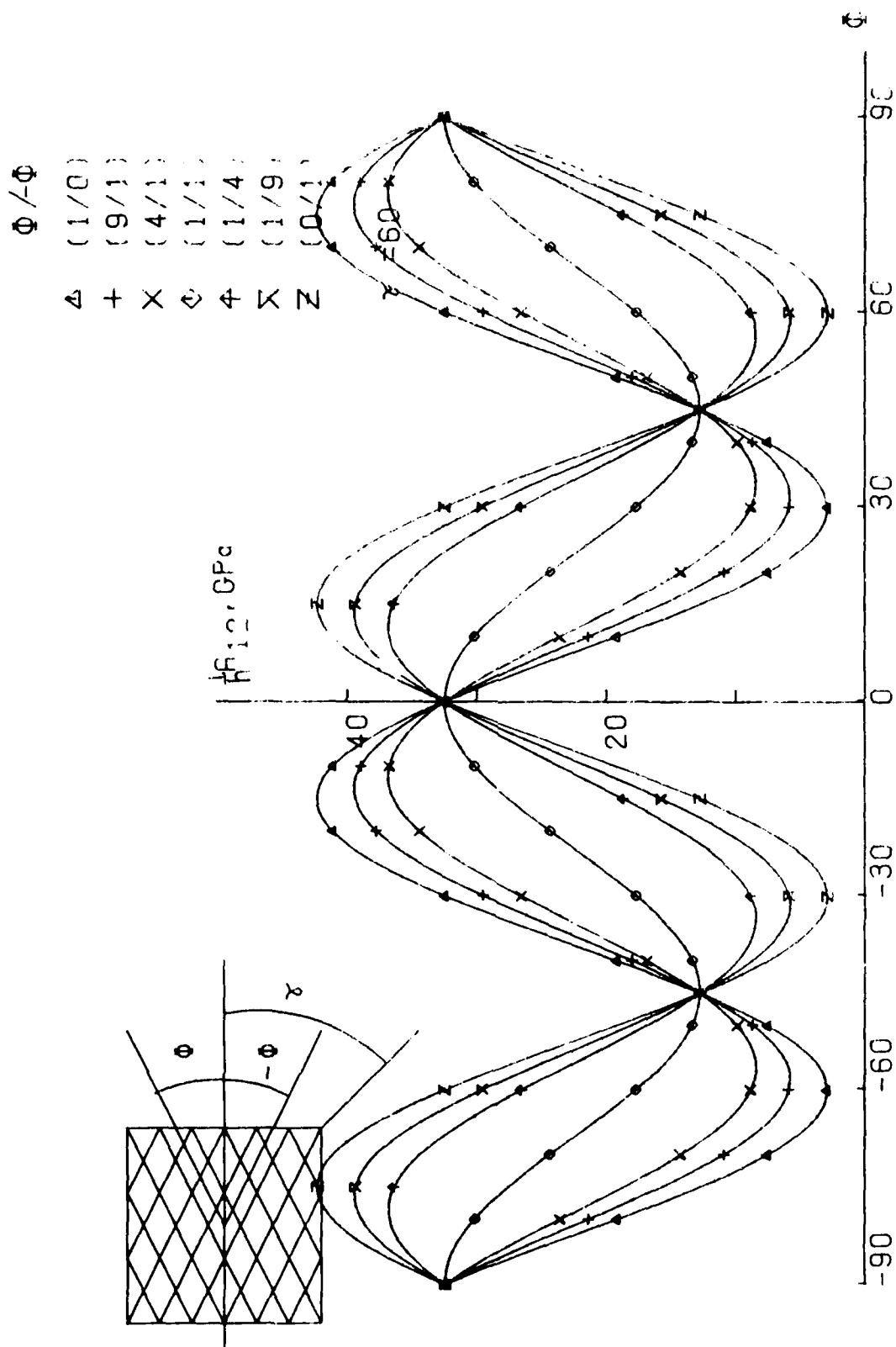


FIG. 42

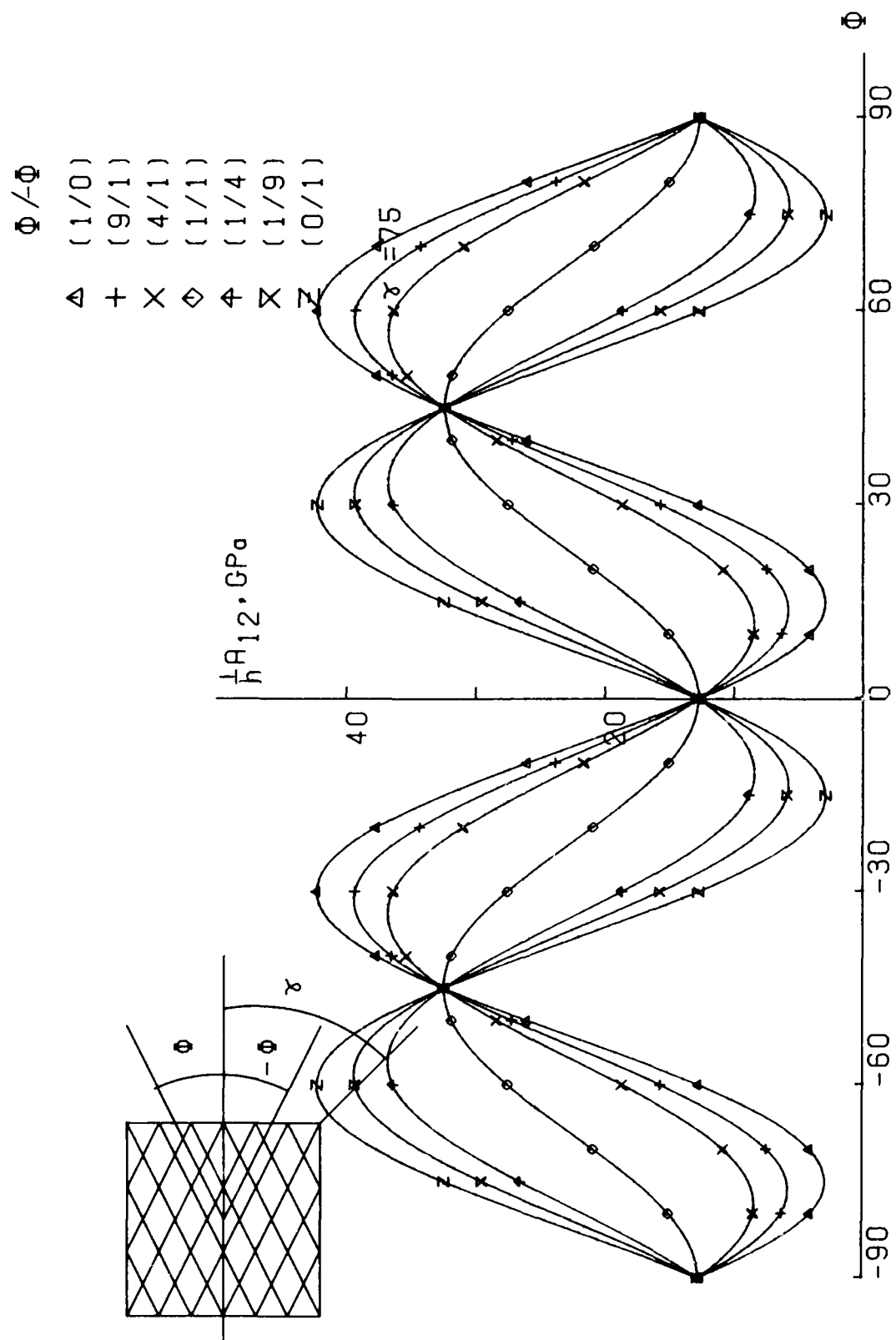


FIG.: 43

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \square (1/4)
 \times (1/9)
 Δ (0/1)

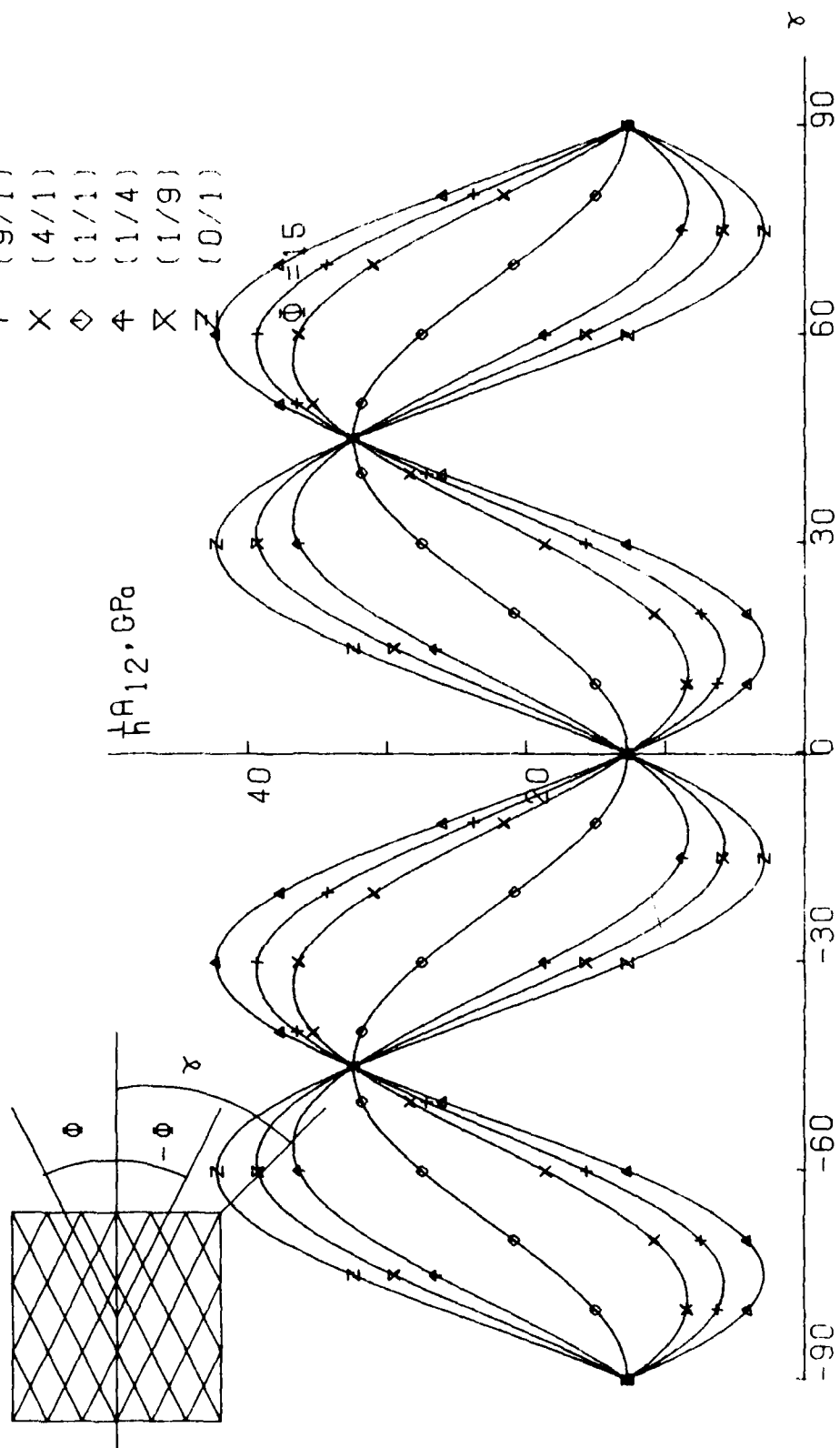


FIG.:44

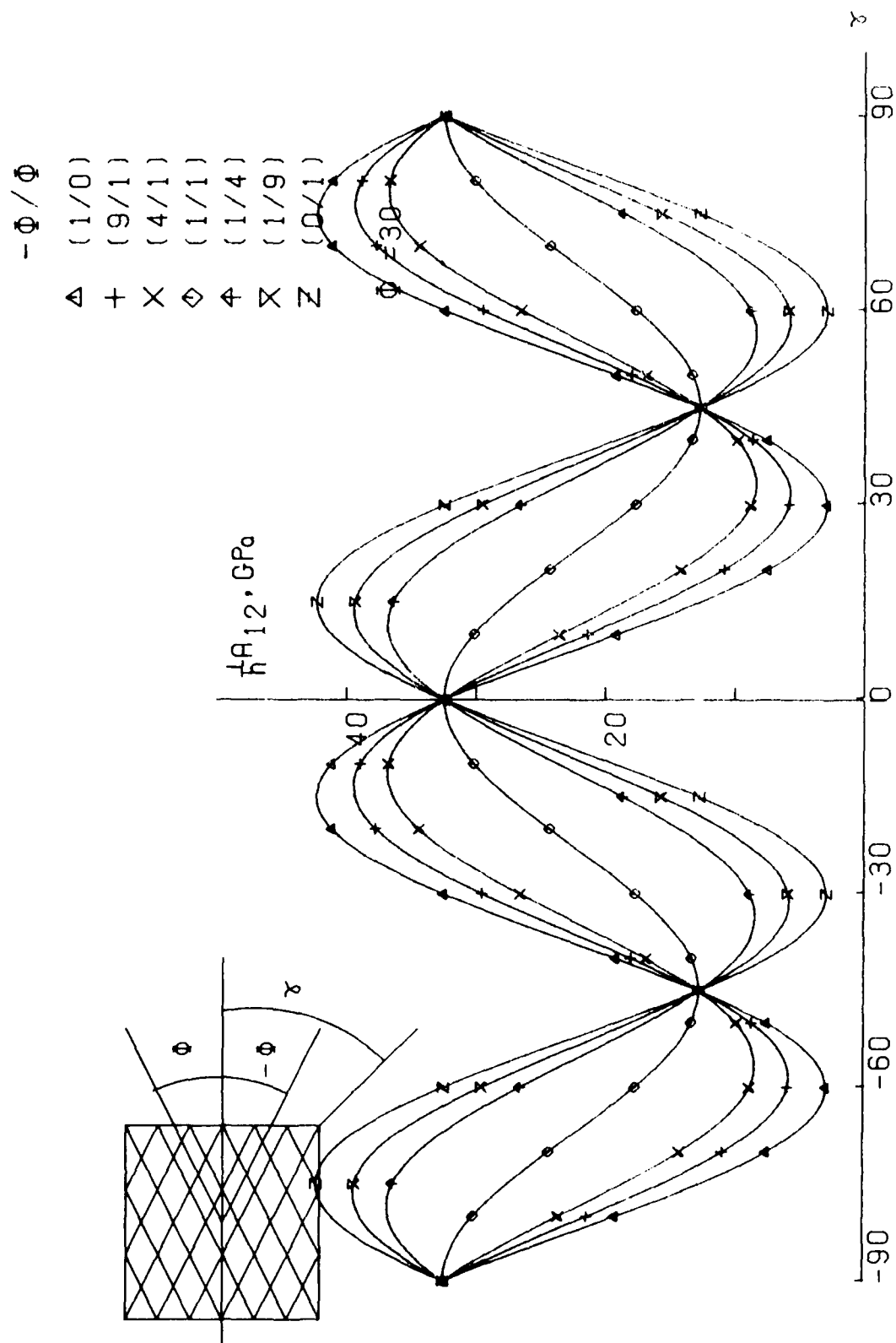


FIG.: 45

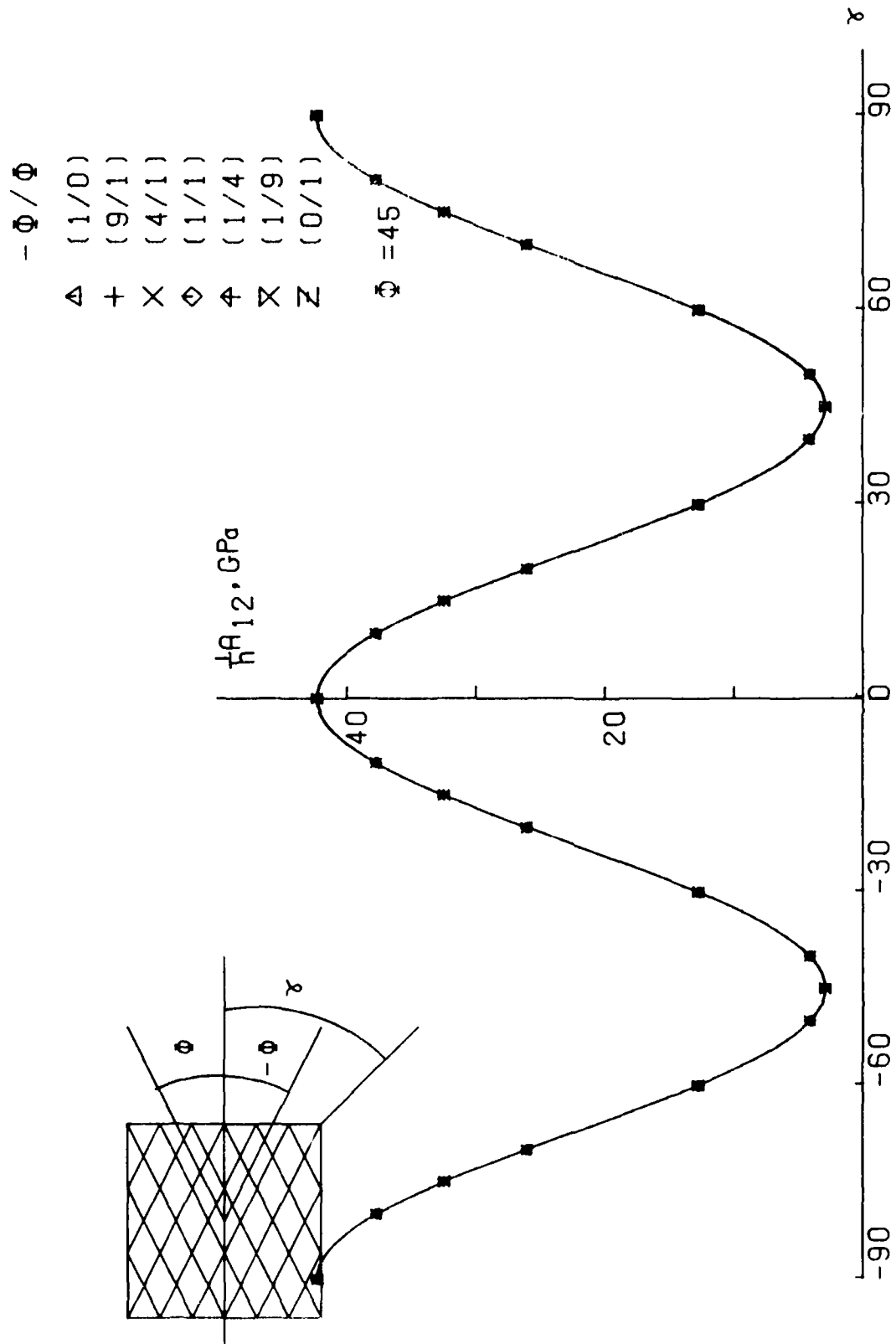


FIG.: 46

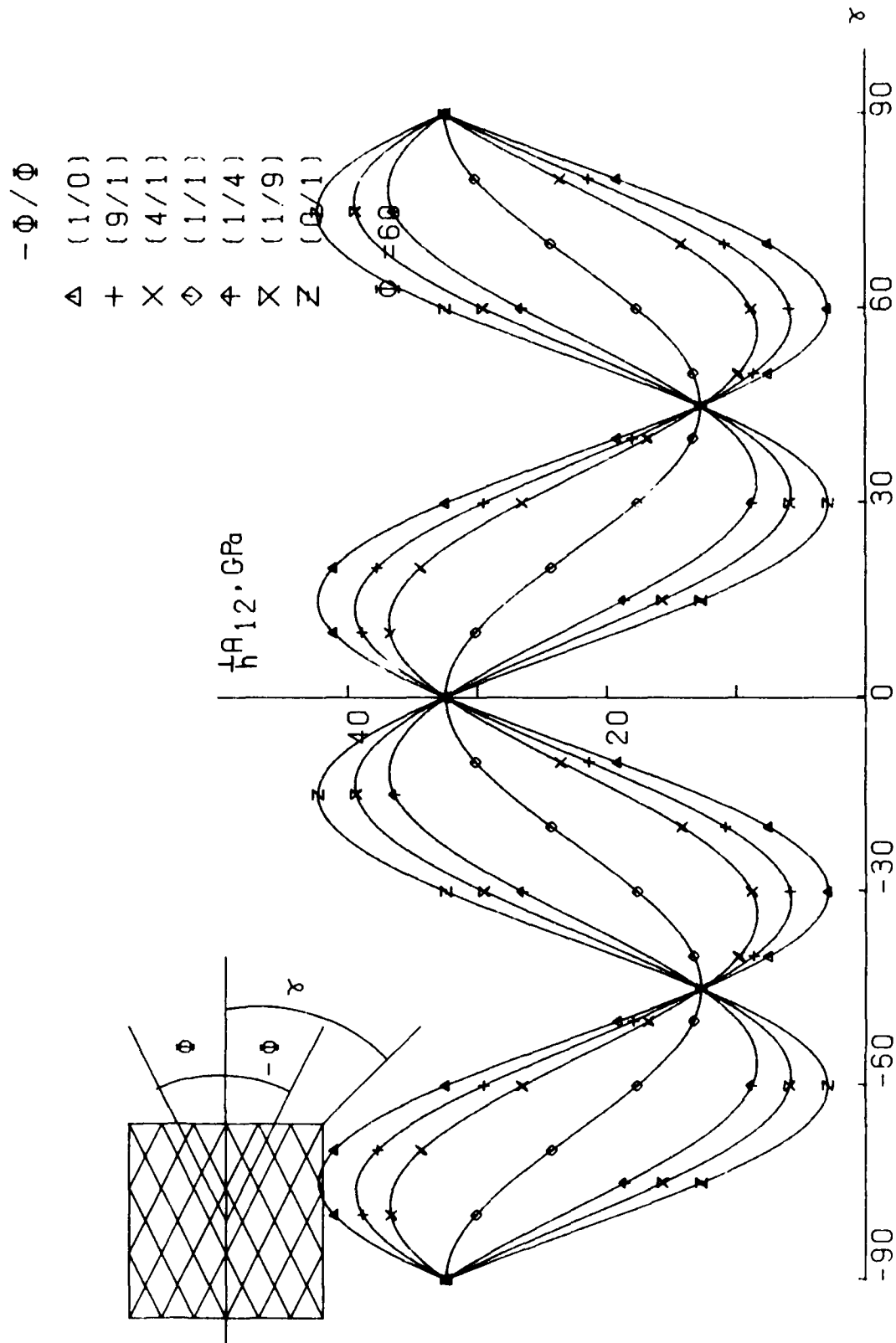


FIG.:47

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

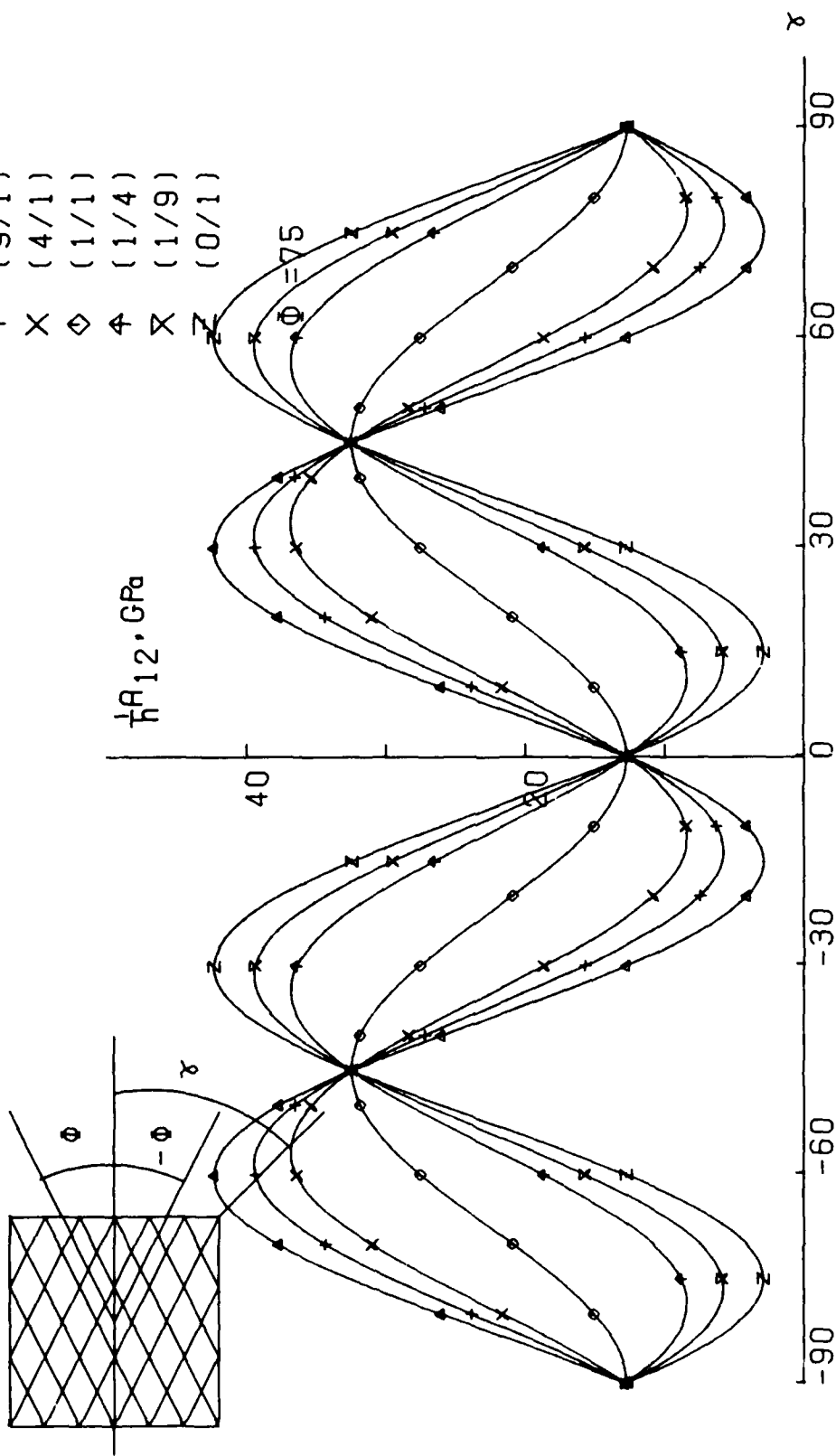


FIG.: 48

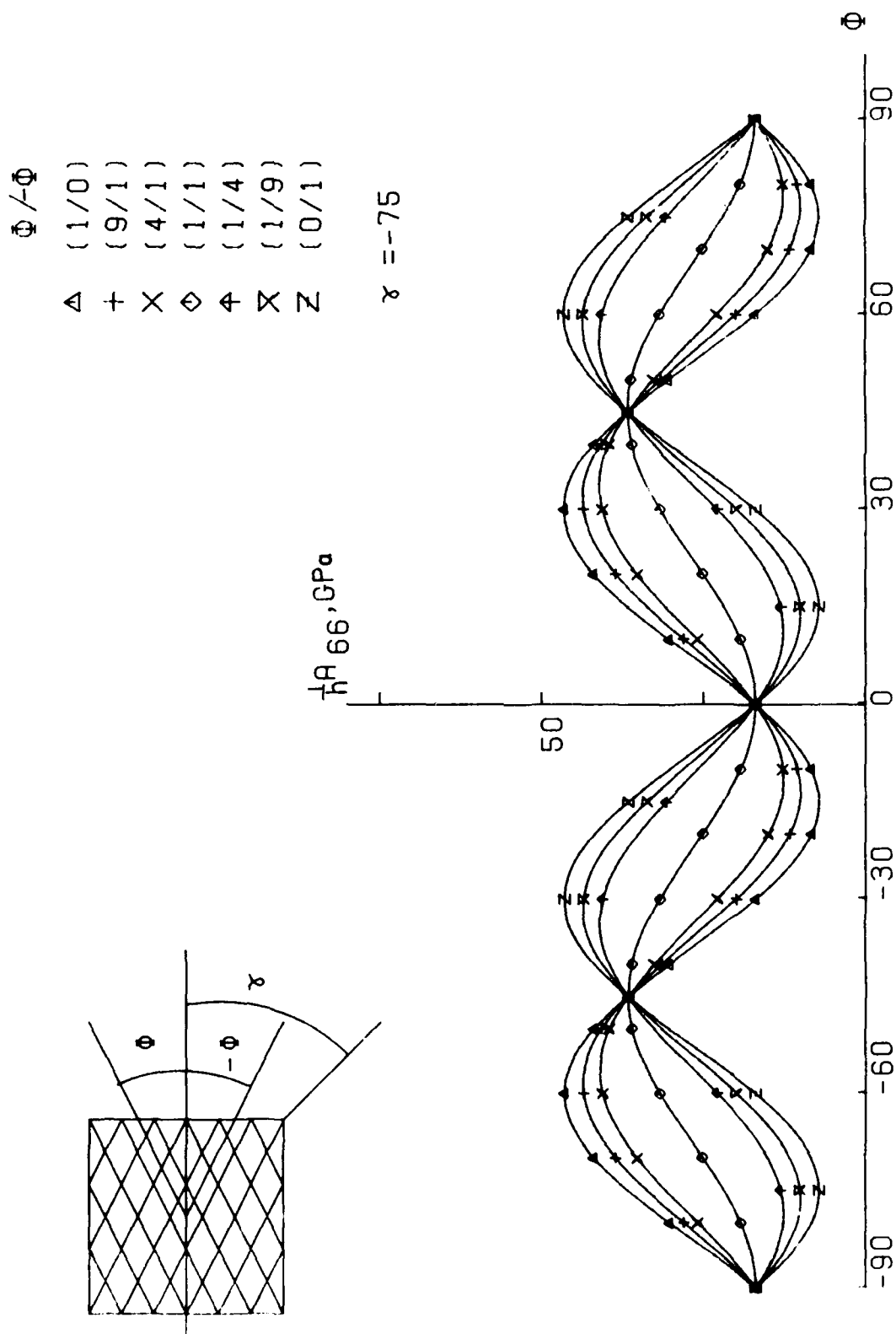
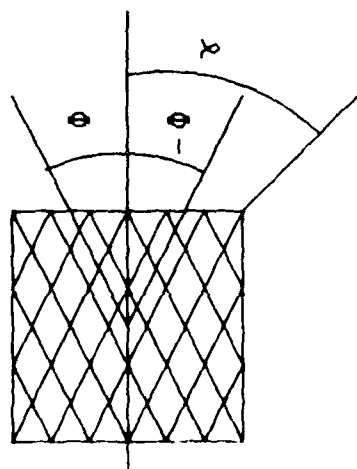


FIG.: 49



ϕ/ϕ

Δ	+	X	\diamond	∇	\times	Σ
(1/0)	(9/1)	(4/1)	(1/1)	(1/4)	(1/9)	(0/1)

$\gamma = -60$

$\frac{1}{h}A_{66}, \text{GPa}$

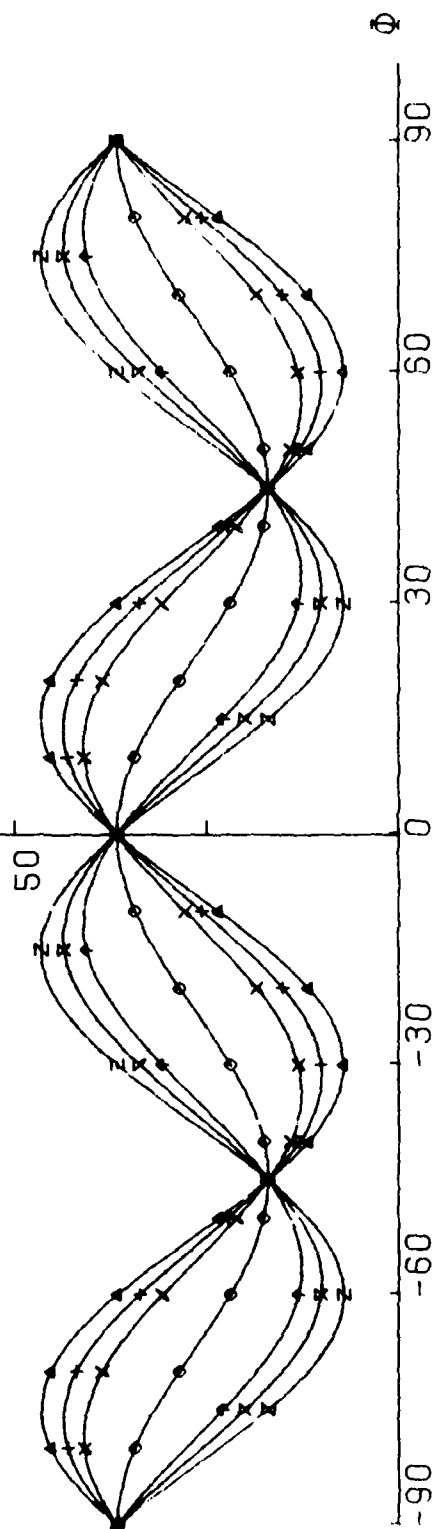
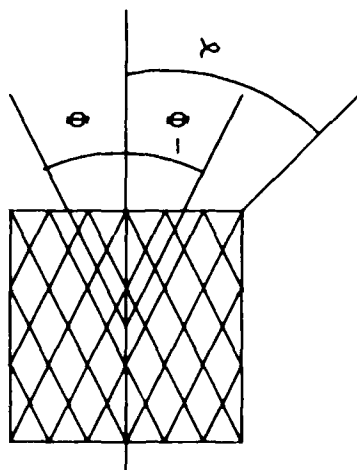


FIG.:50



Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 \ominus (0/1)

$\gamma = -45$

$\frac{1}{h} A_{66}, \text{GPa}$

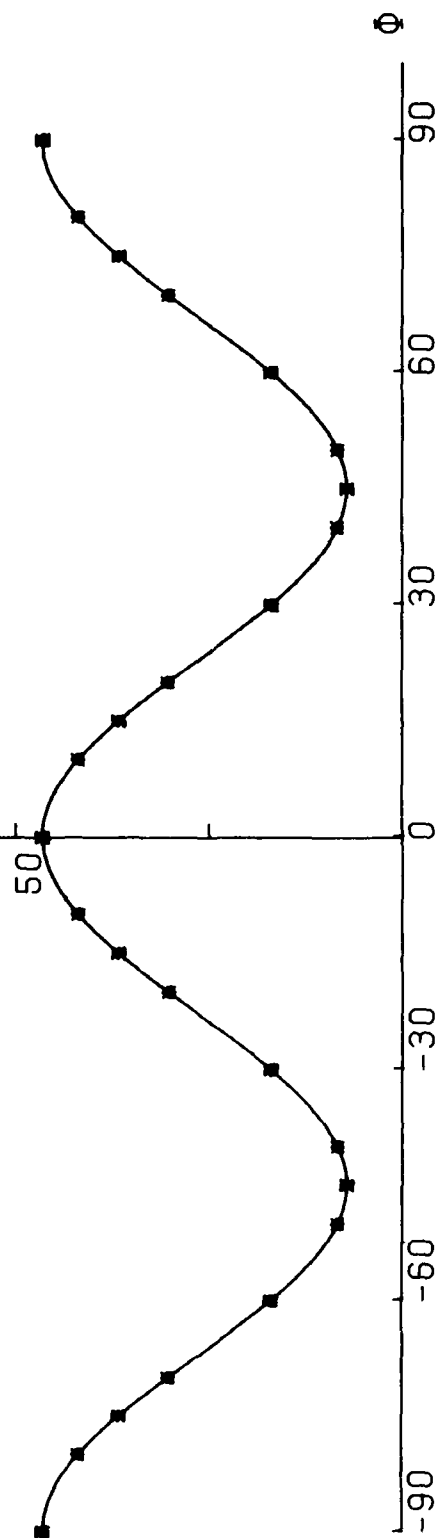
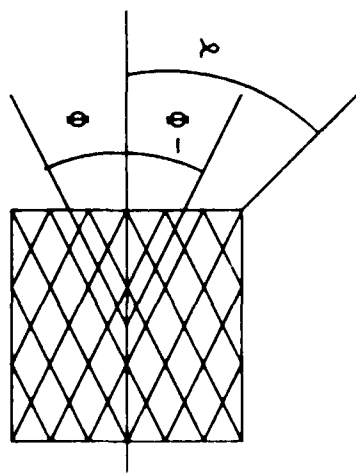


FIG.: 51



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\chi = -30$

$\frac{1}{h}A_{66}, \text{GPa}$

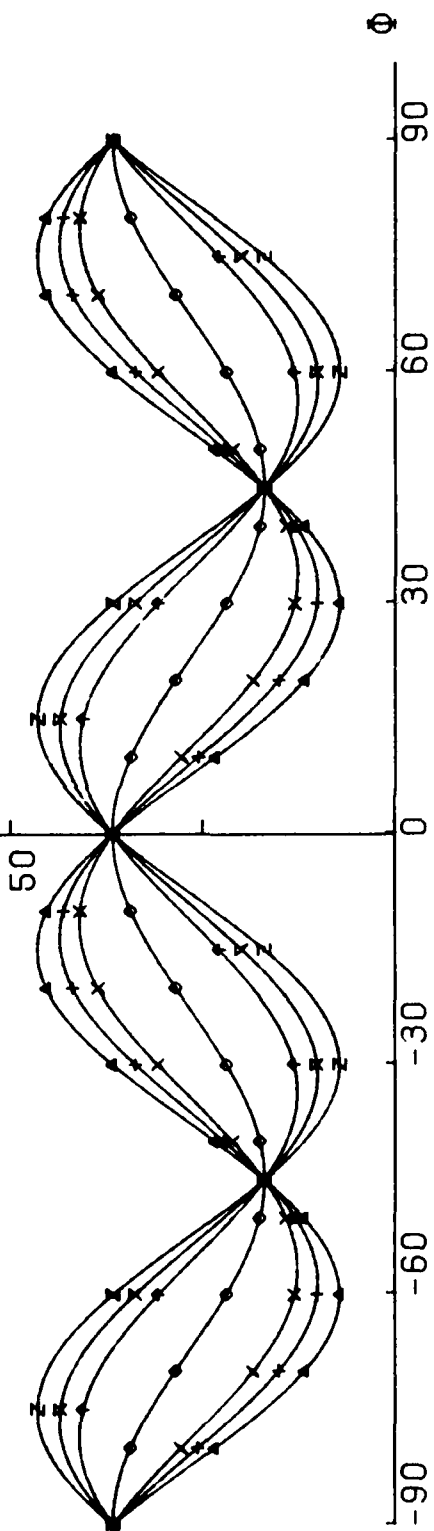
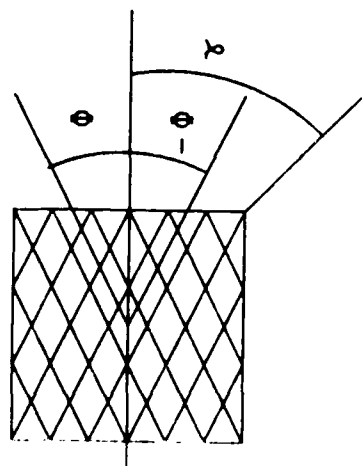


FIG.:52



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = -15$

$\frac{1}{h} A_{66}, \text{GPa}$

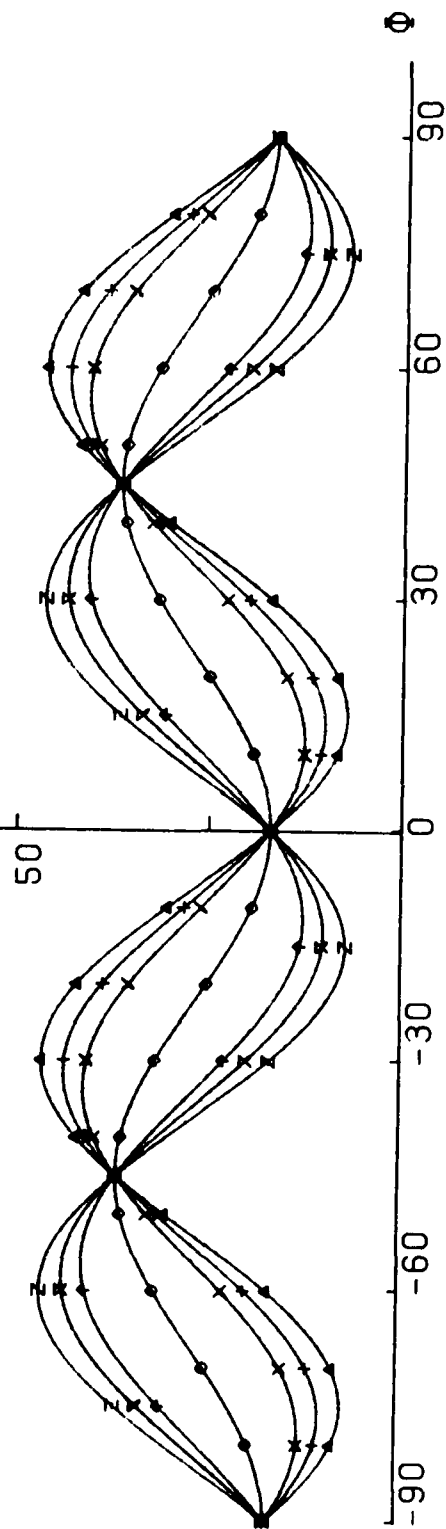


FIG.:53

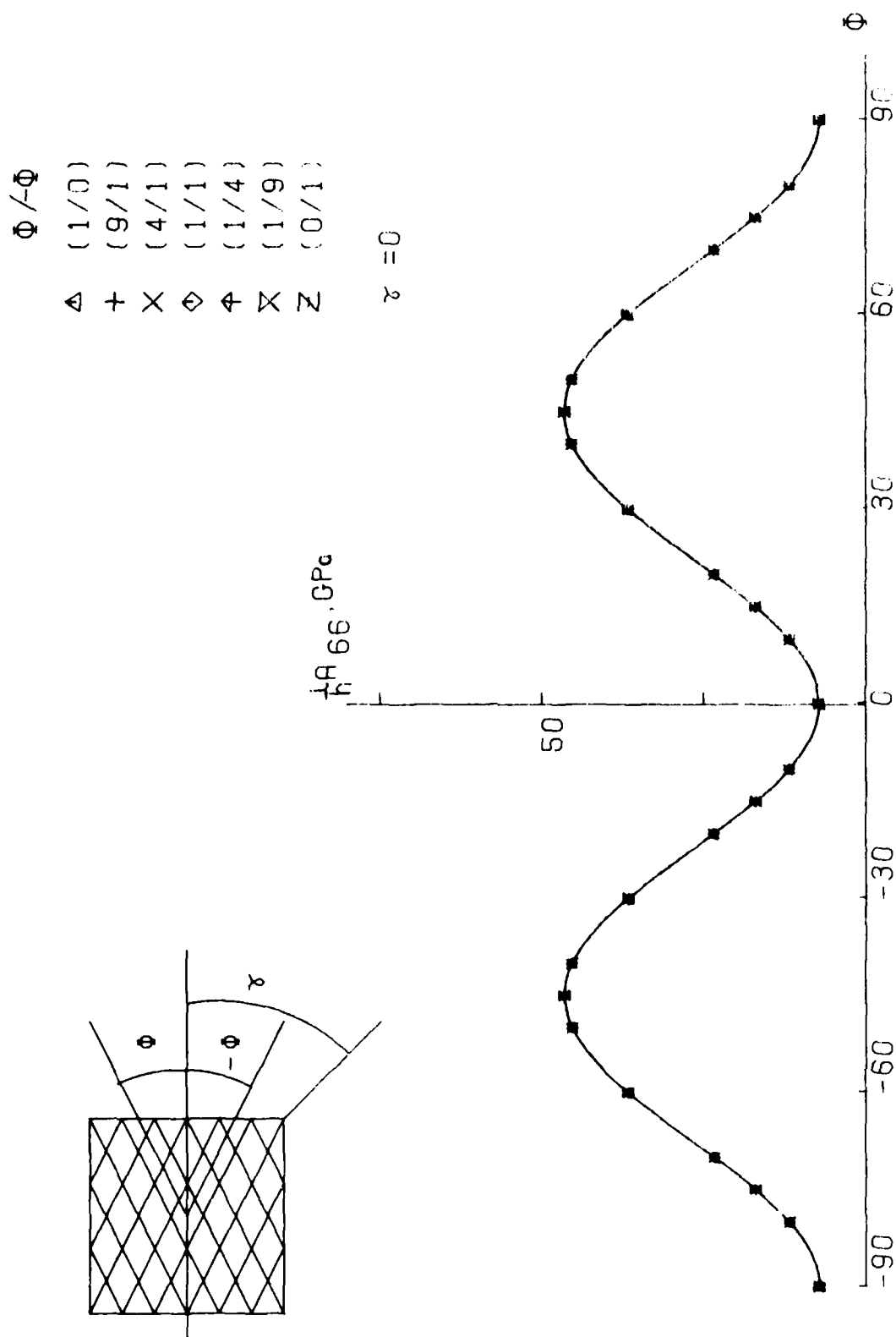
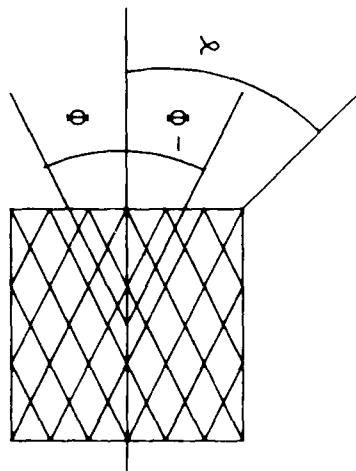


FIG.:54



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\chi = 15$

$\mu = 66.6 \text{ GPa}$

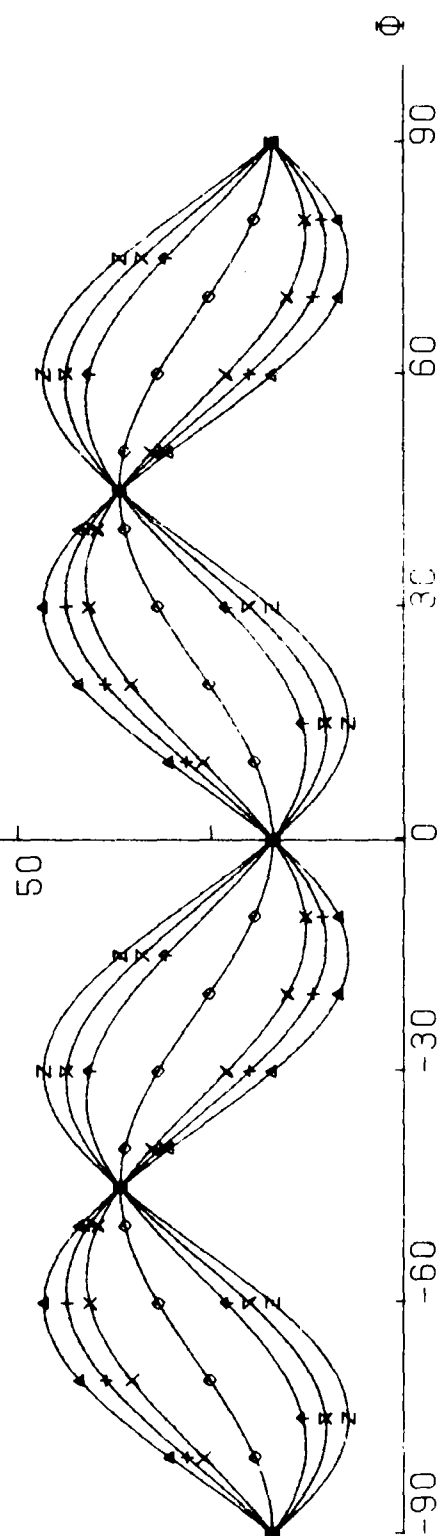
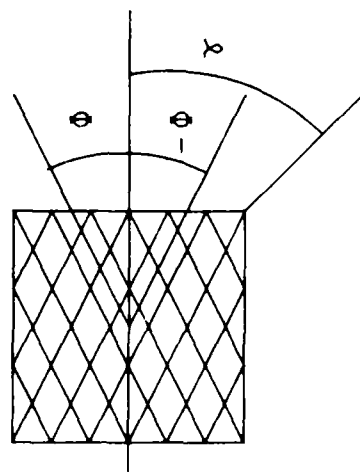


FIG.:55



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = 30$

$\frac{1}{h} A_{66}, \text{GPa}$

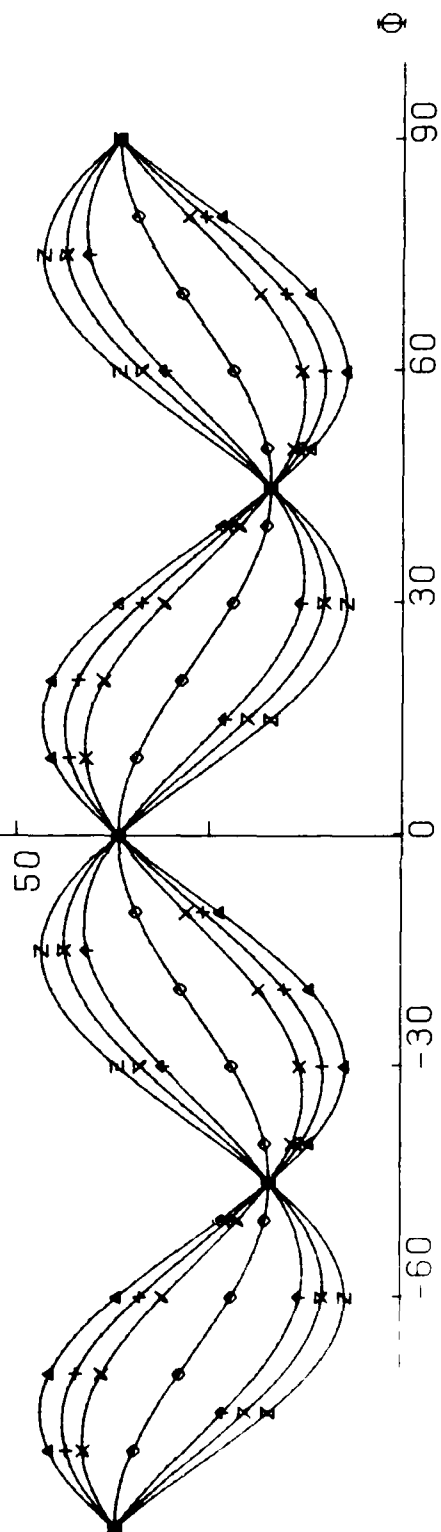


FIG.:56

AD-A093 227

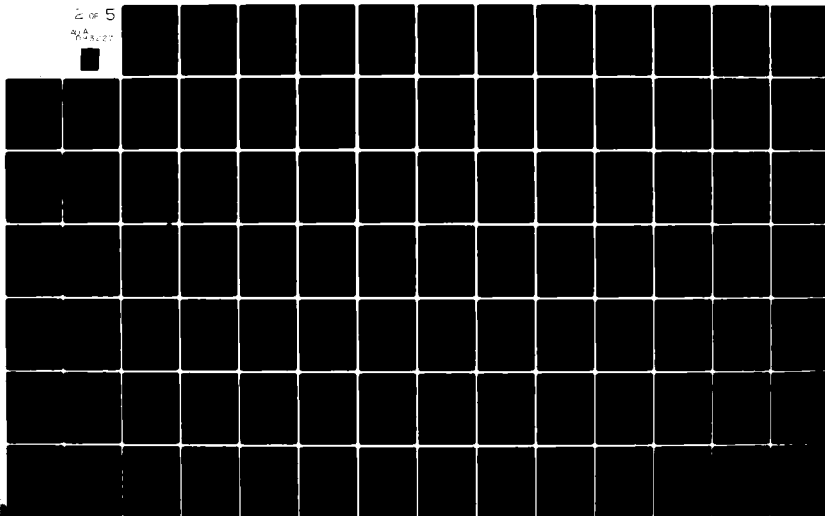
AIR FORCE WRIGHT AERONAUTICAL LABS WRIGHT-PATTERSON AFB OH F/G 11/4
ELASTIC PROPERTIES OF T300/5208 BIDIRECTIONAL SYMMETRIC LAMINAT--ETC(U)
SEP 80 S R SONI
AFWAL-TR-80-4111

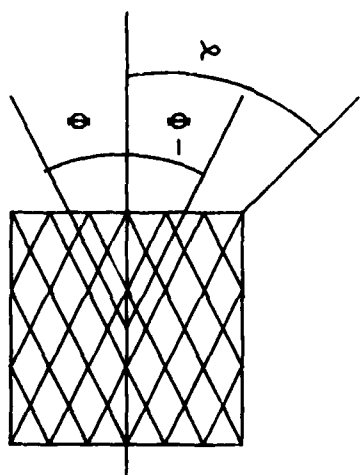
UNCLASSIFIED

NL

2 OF 5

AD-A093 227





$\phi / -\phi$
 $(1/0)$
 $(9/1)$
 $(4/1)$
 $(1/1)$
 $(1/4)$
 $(1/9)$
 $(0/1)$

Δ + X \diamond ∇ X Σ

$\gamma = 45$

$\frac{1}{h} A_{66}, \text{GPa}$

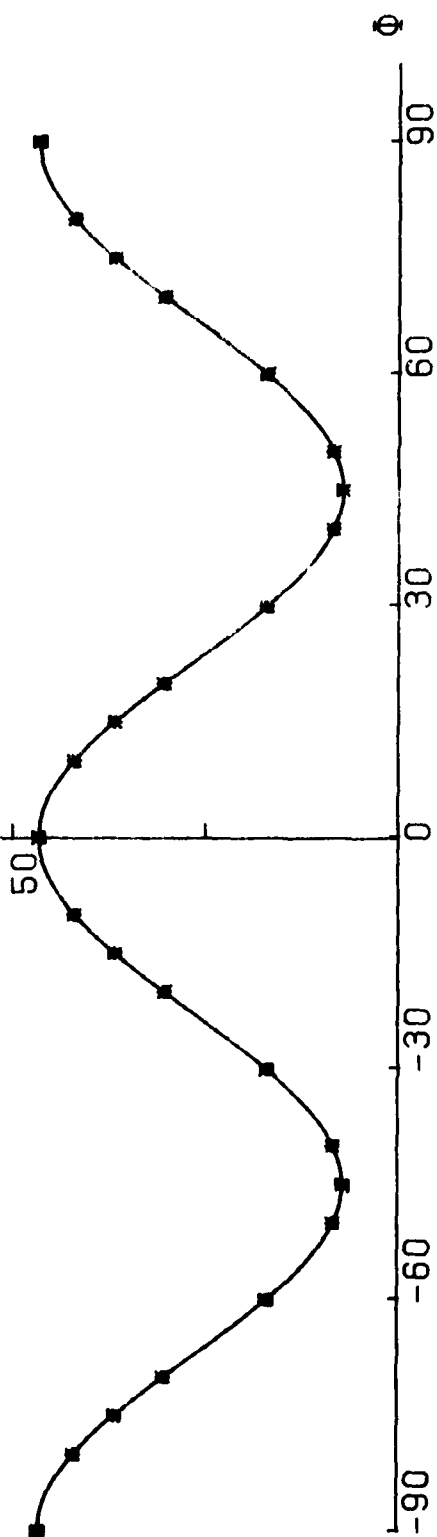
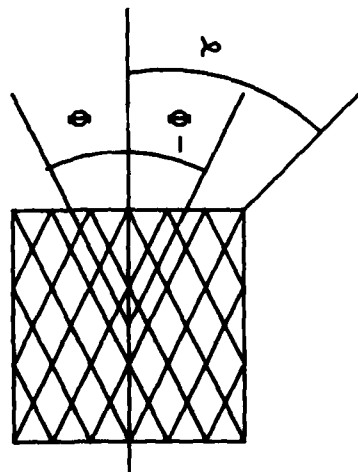


FIG.:57



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 Σ (1/9)
 Z (0/1)
 $\gamma = 60$

$\frac{1}{h} A_{66}, \text{GPa}$

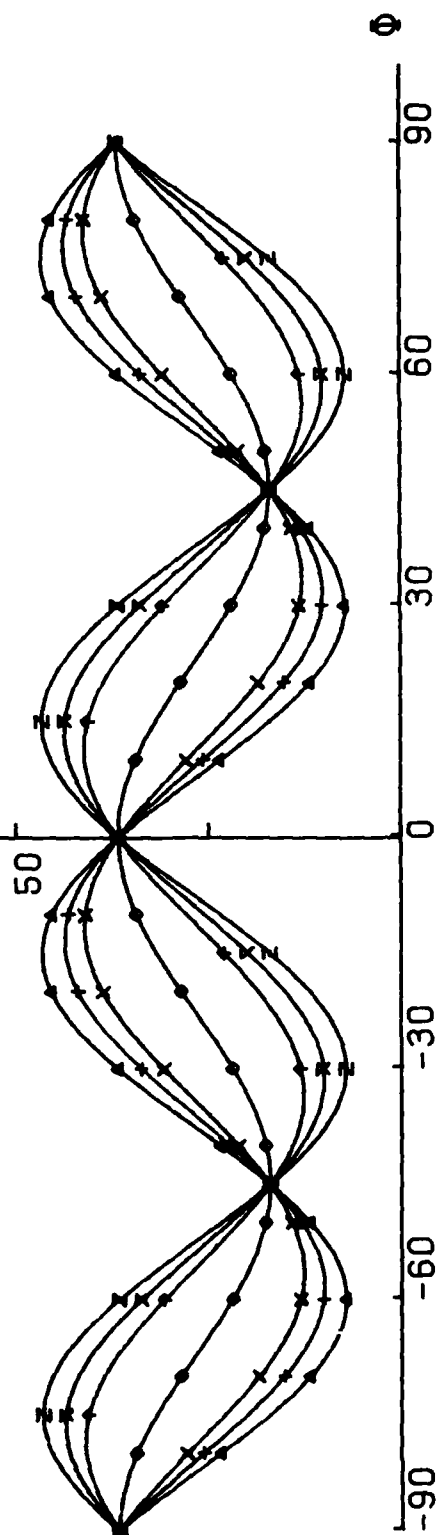
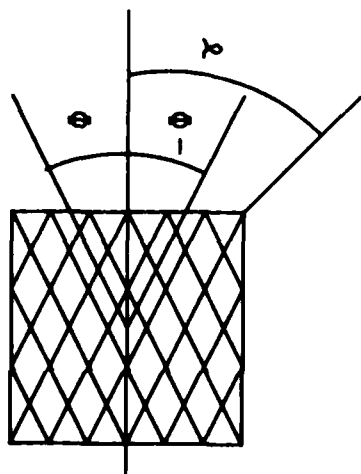


FIG.:58



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = 75^\circ$

$\frac{1}{h} A_{66}, \text{GPa}$

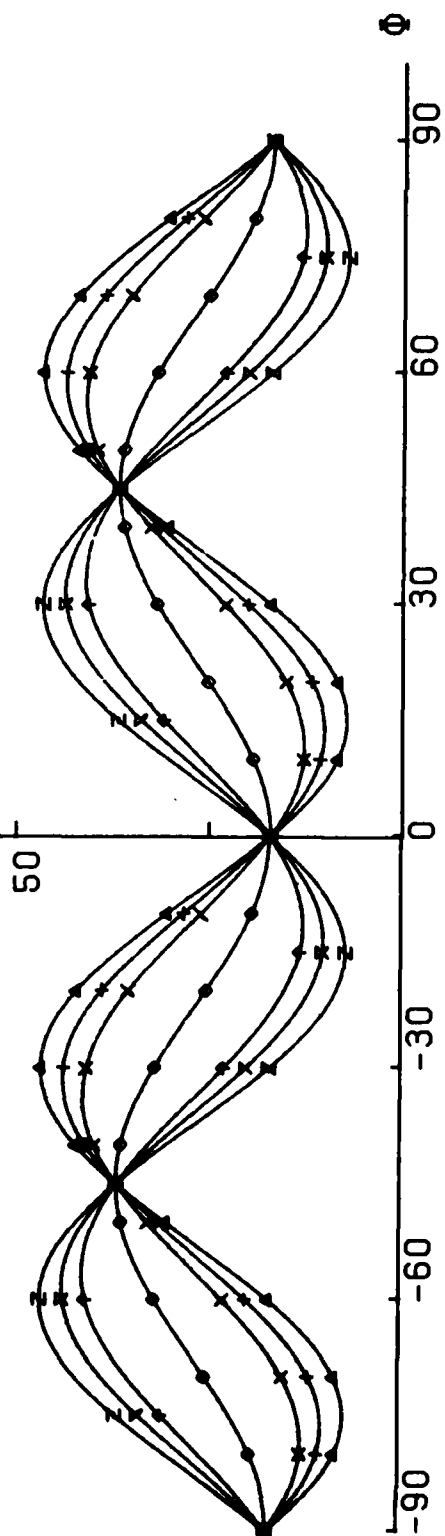
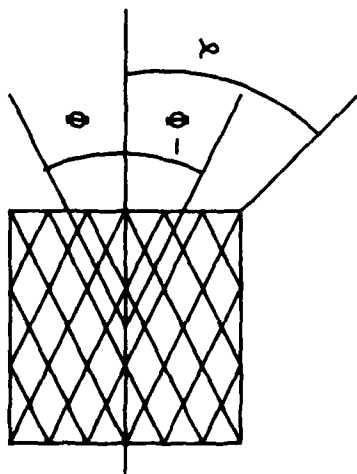


FIG.: 59



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\phi = 15$

$\frac{1}{2}A_{66}, \text{ GPa}$

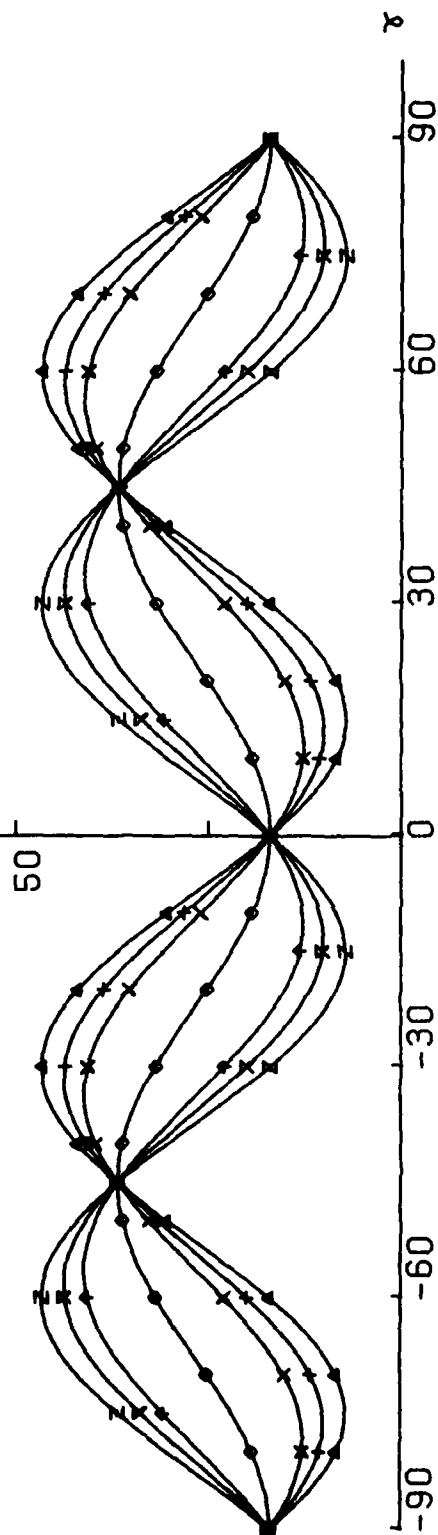
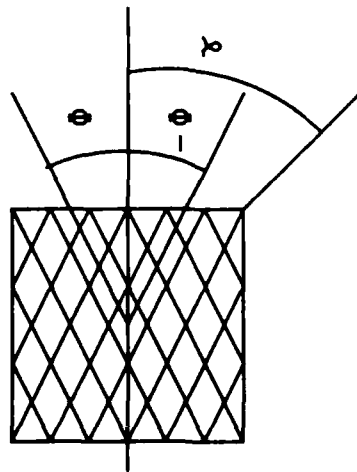


FIG.:60



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)
 $\phi = 30$

$\frac{1}{h}A_{66}, \text{GPa}$

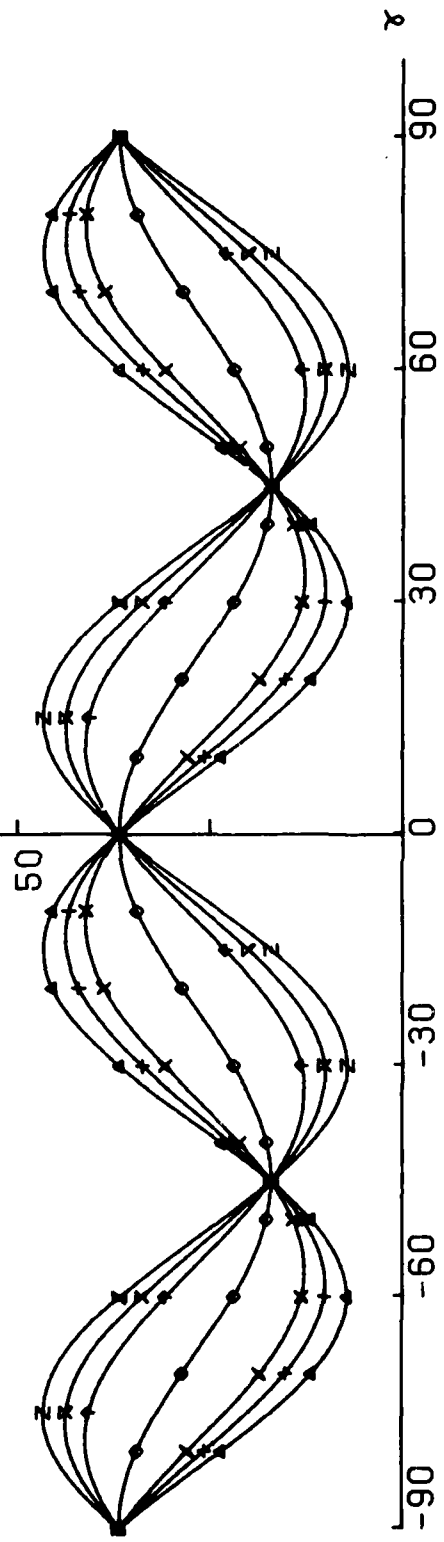
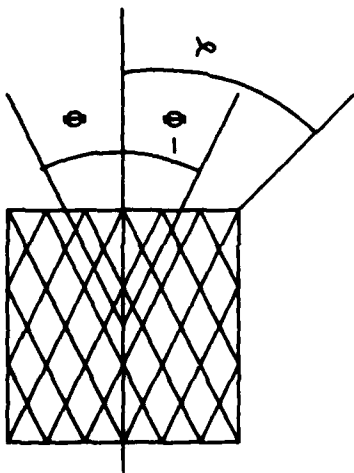


FIG.:61



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\Phi = 45$

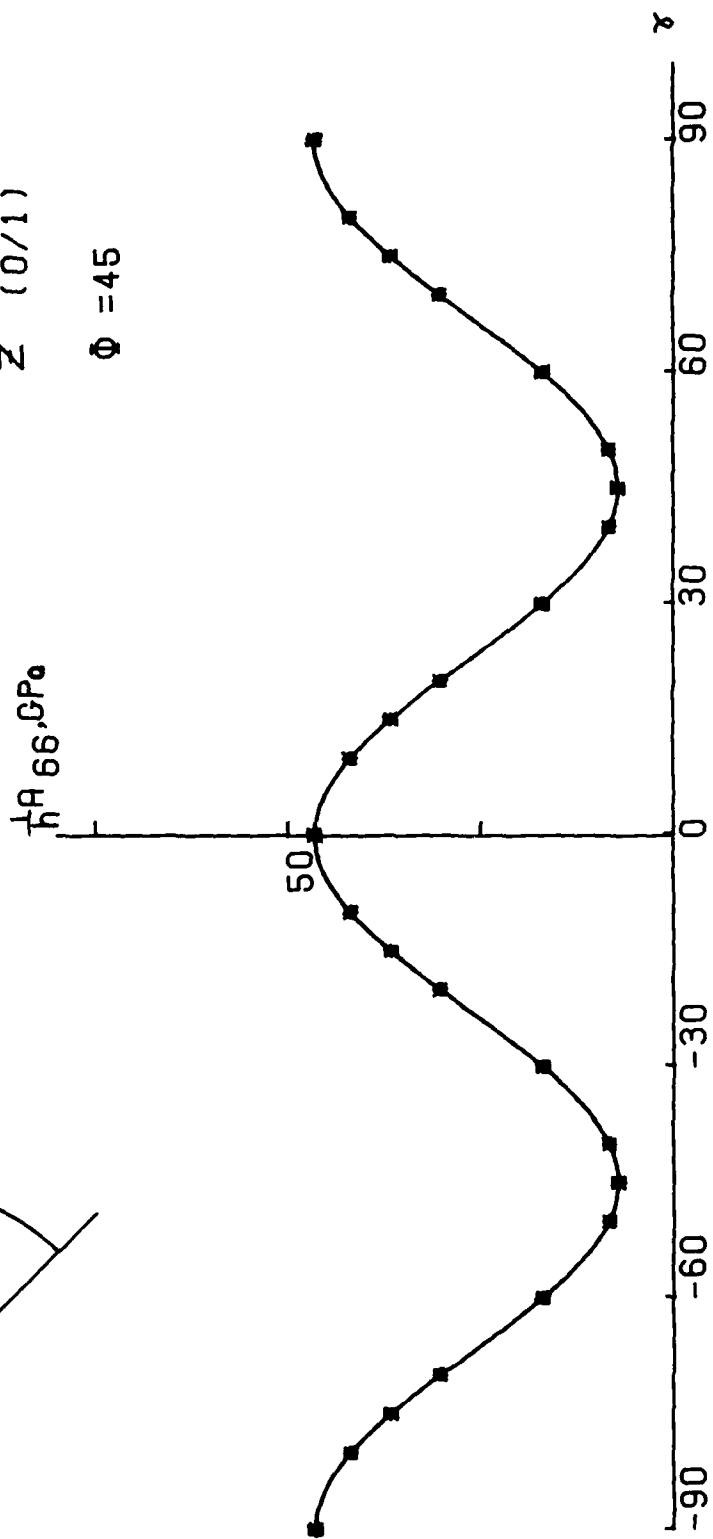
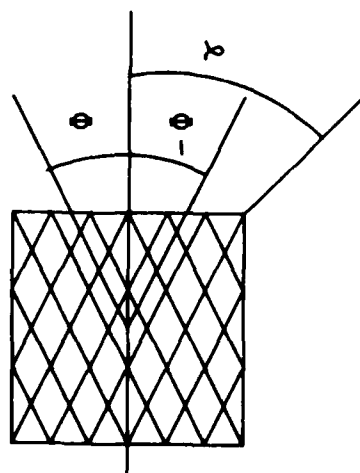


FIG. : 62



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)
 $\phi = 60$

$\frac{1}{h} A_{66}, \text{GPa}$

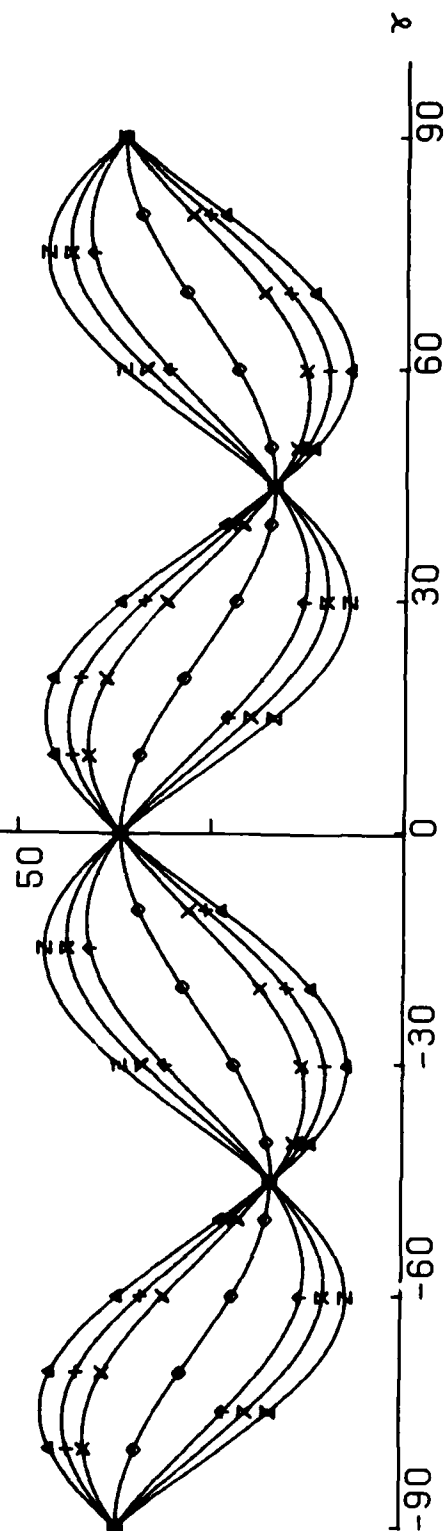
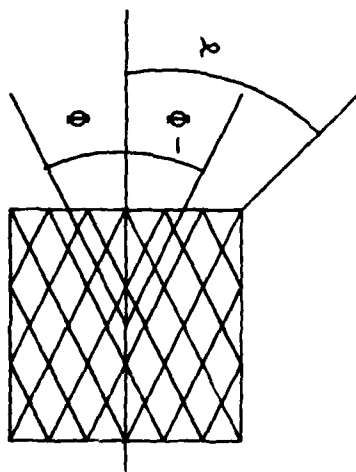


FIG.: 63



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \times (1/9)
 Σ (0/1)

$\phi = 75$

$\frac{1}{h}A_{66}, \text{ GPa}$

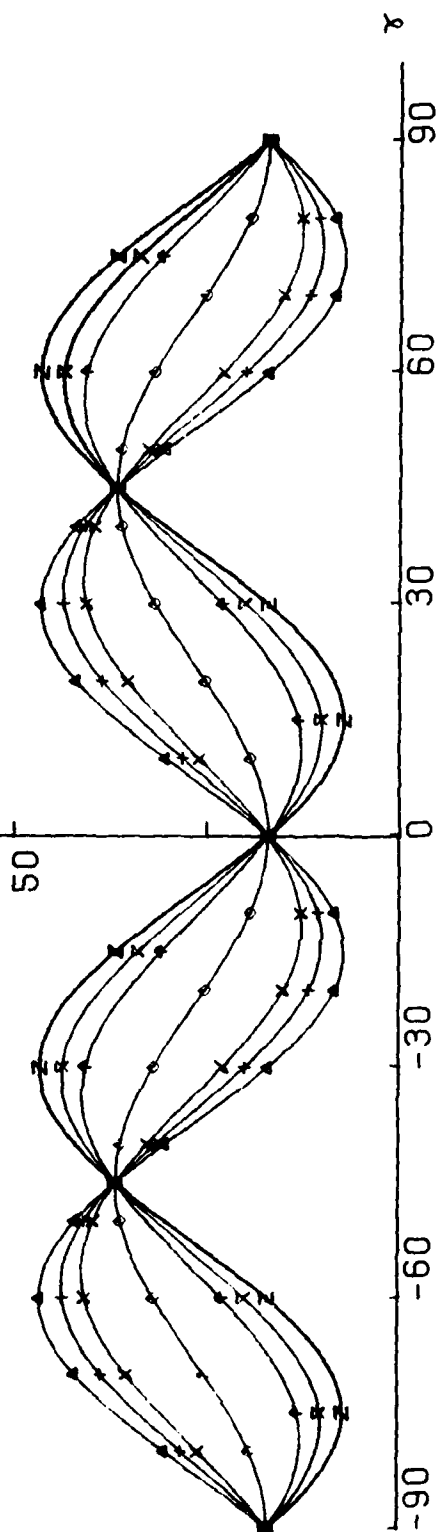
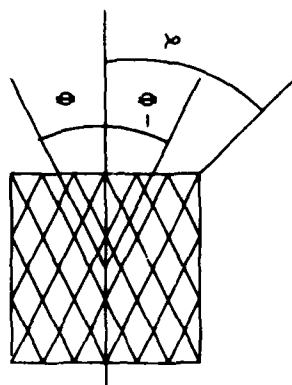


FIG.:64



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Z (0/1)

$\gamma = -75$

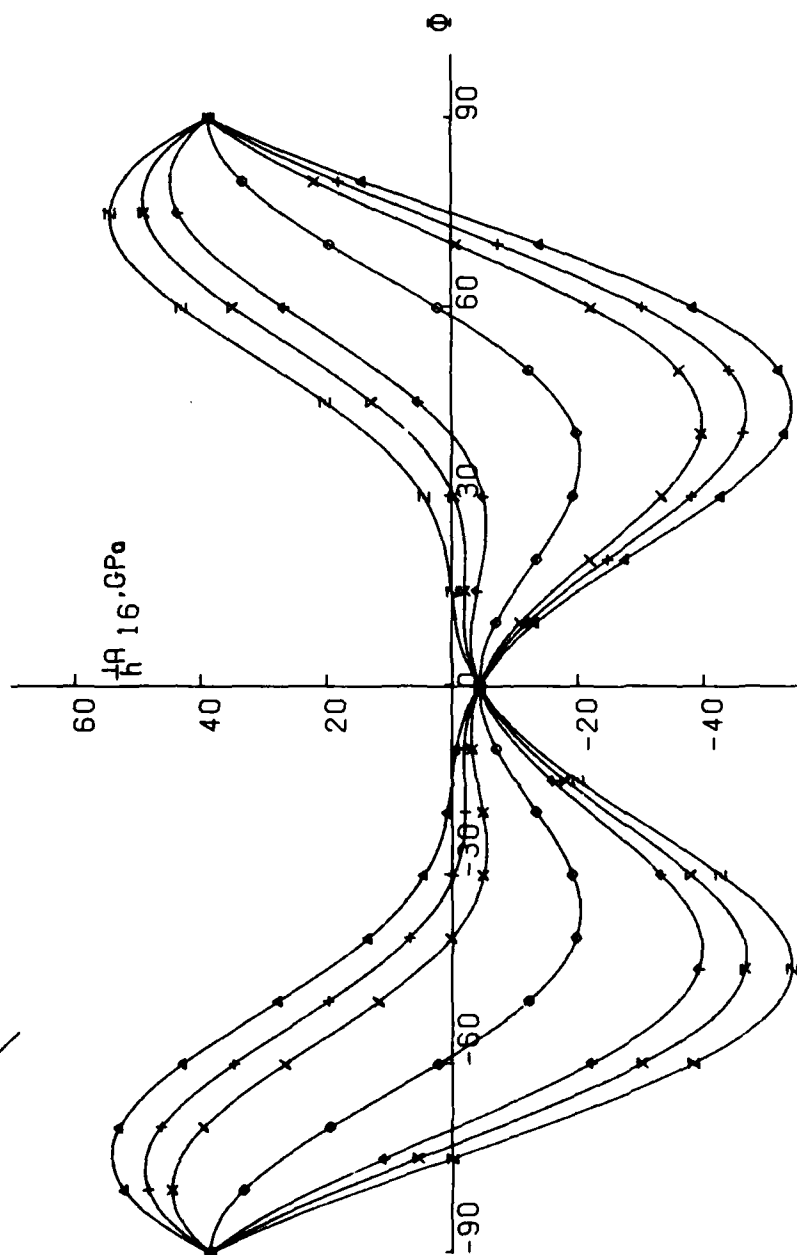
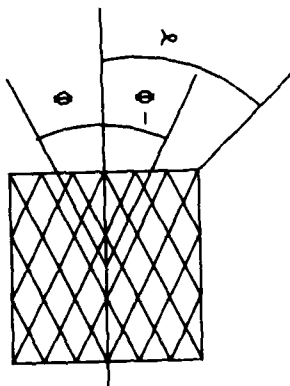


FIG.:65



ϕ/Φ

Δ	(1/0)
+	(9/1)
X	(4/1)
\diamond	(1/1)
Φ	(1/4)
X	(1/9)
Z	(0/1)

$\chi = -60$

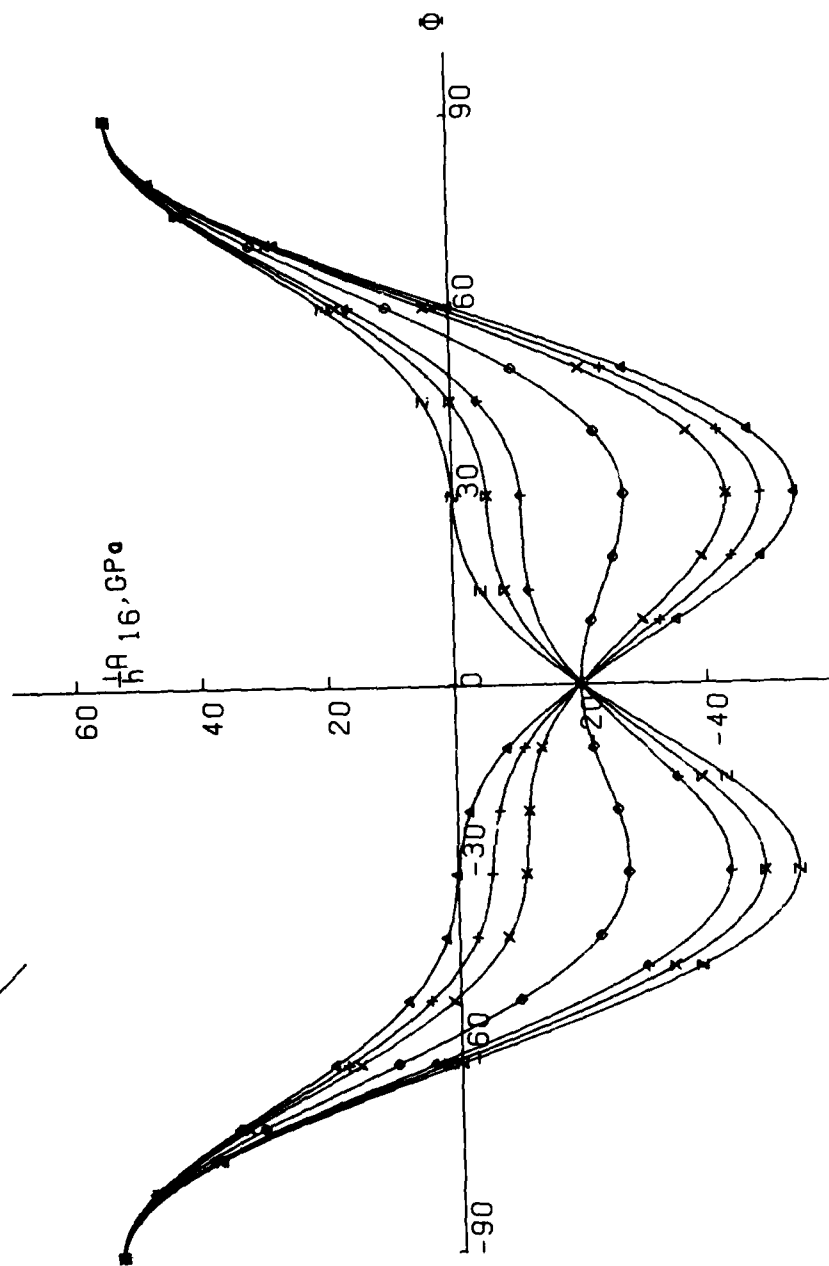


FIG.: 66

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Σ (0/1)
 $\chi = -45$

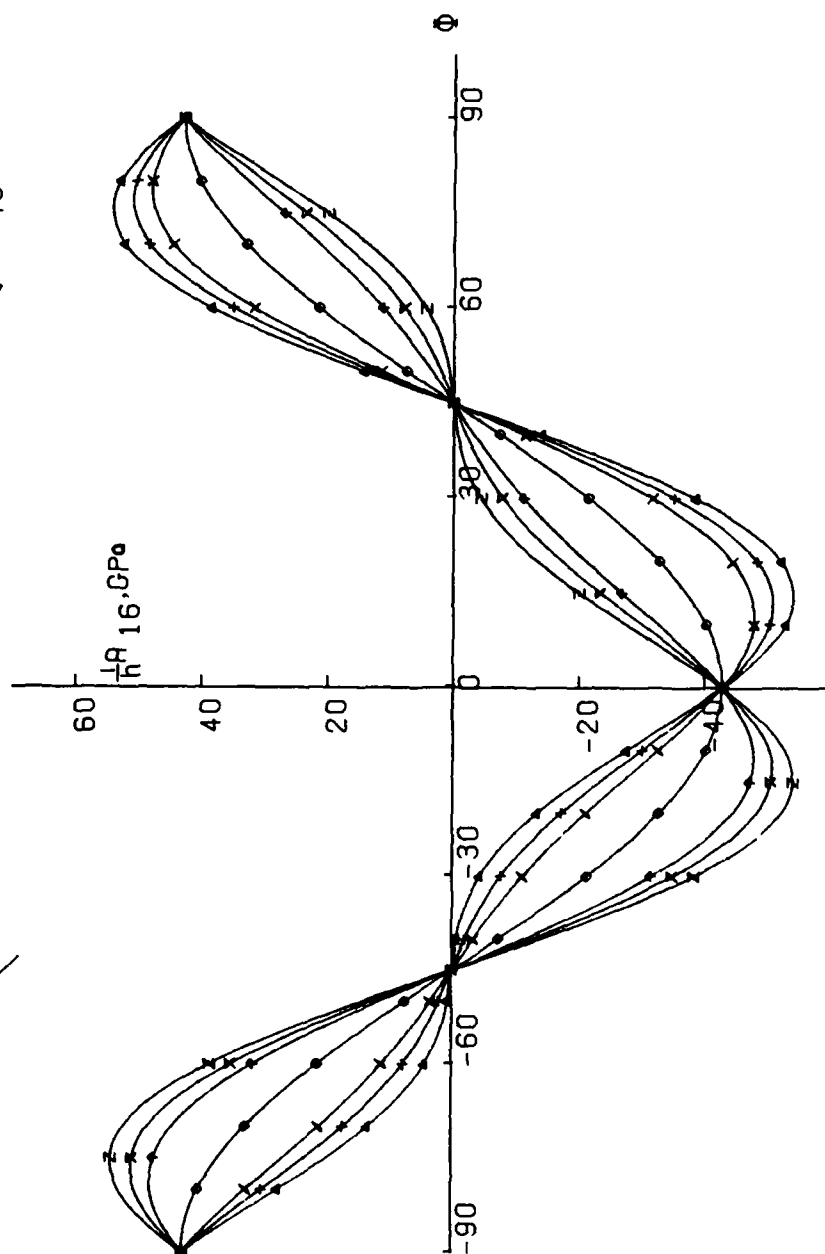
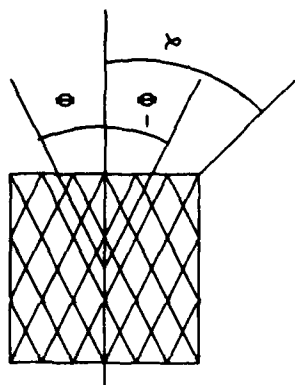
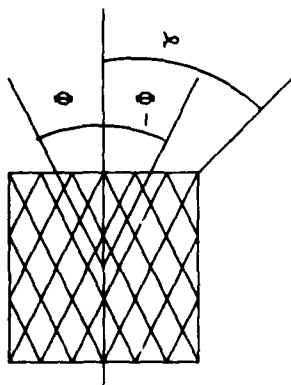


FIG.:67



Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = -30$

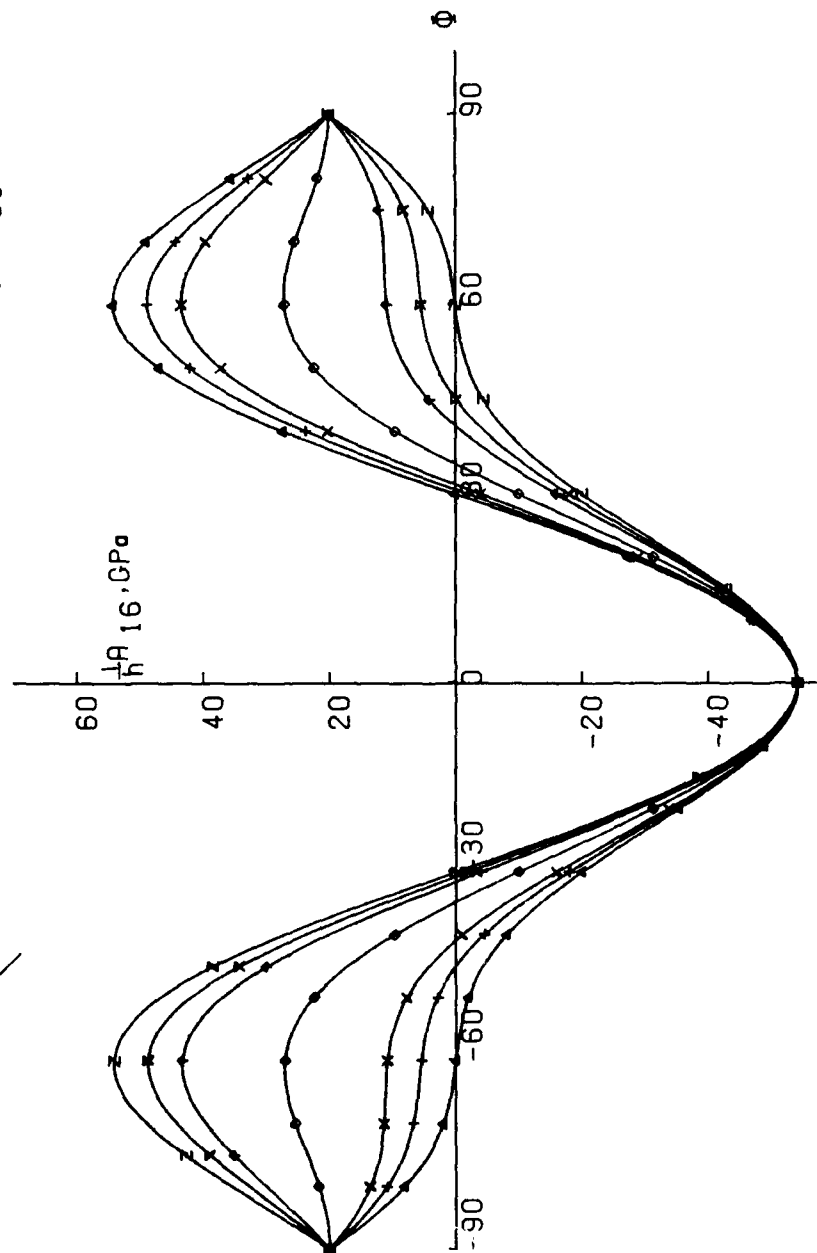


FIG.: 68

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = -15$

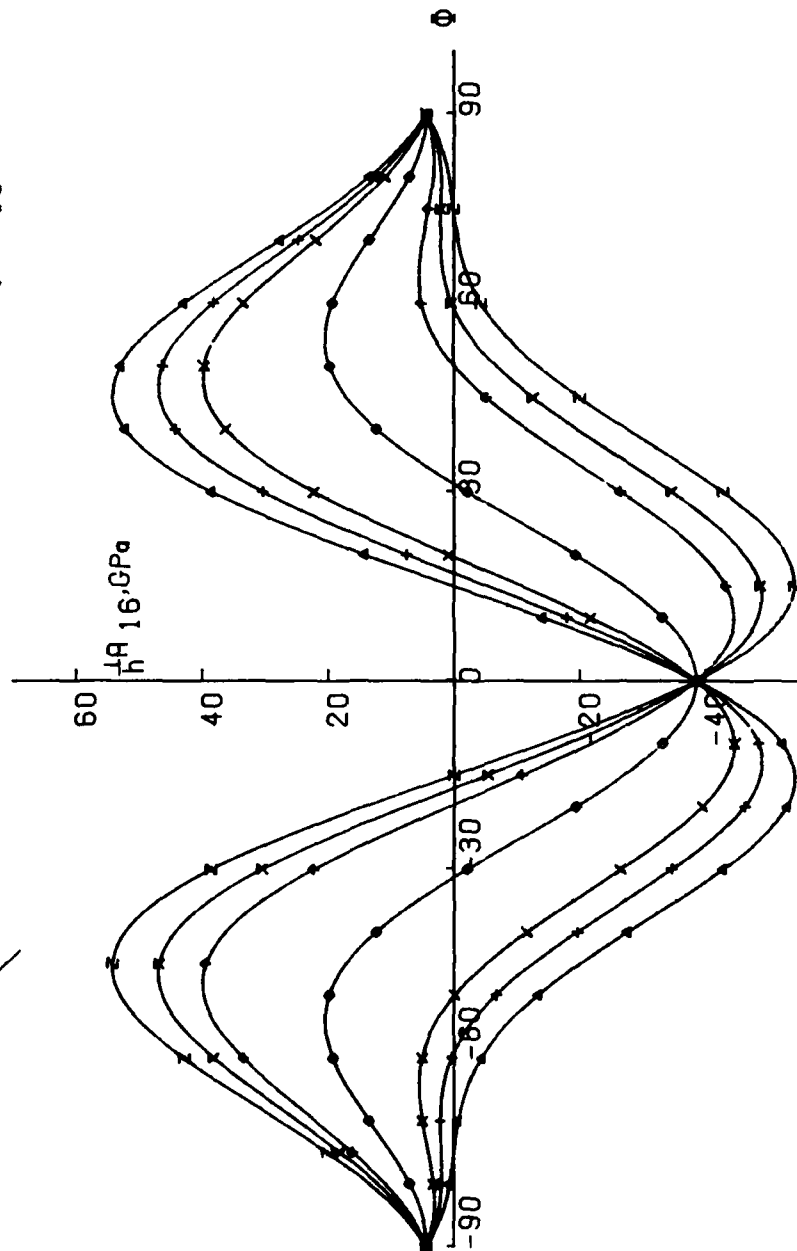
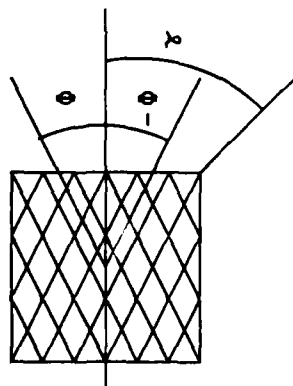
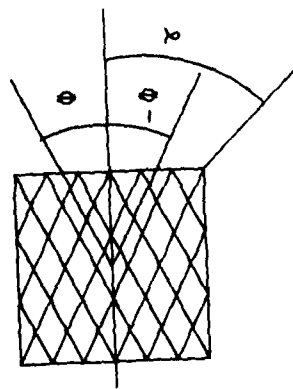


FIG.:69



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 \times (1/9)
 Σ (0/1)
 $\gamma = 0$

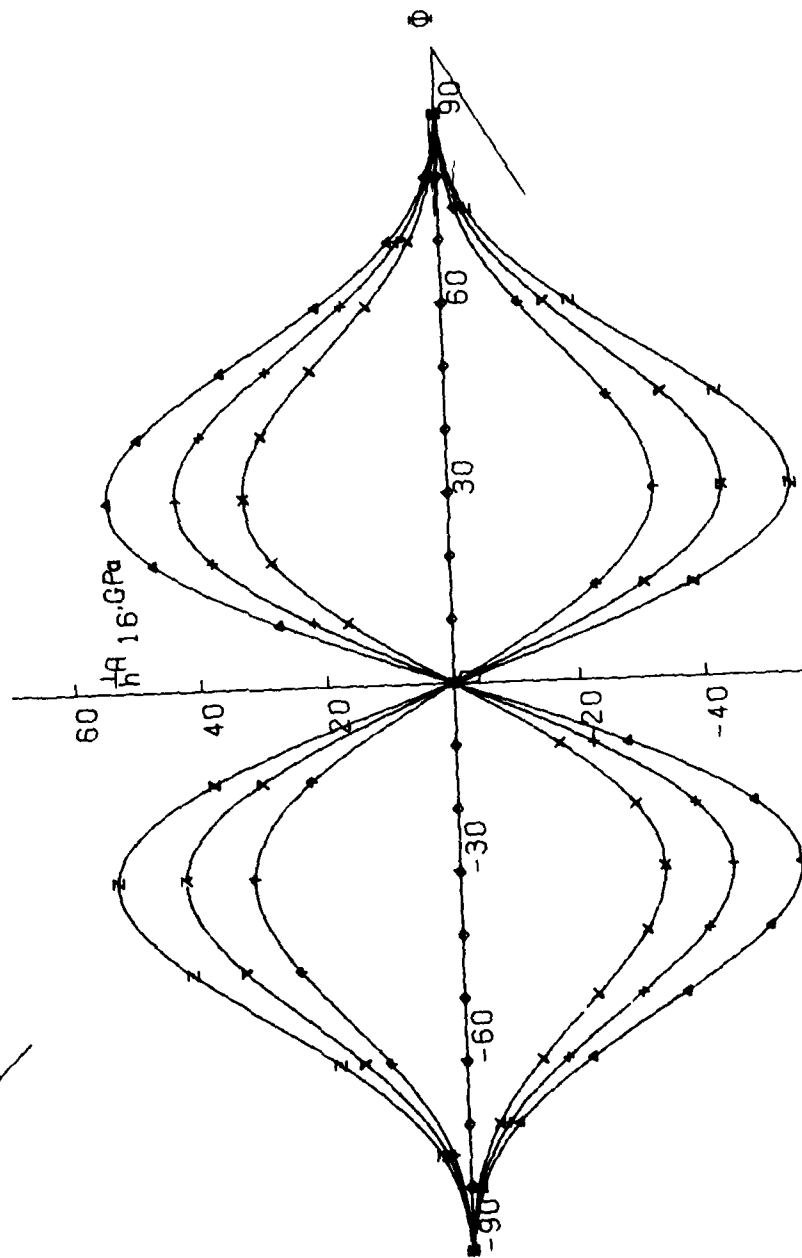
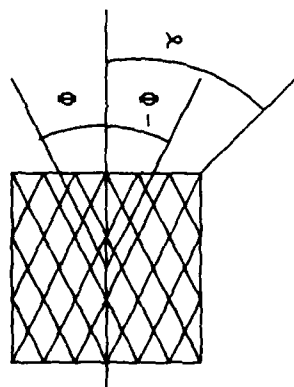


FIG.: 70



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = 15$

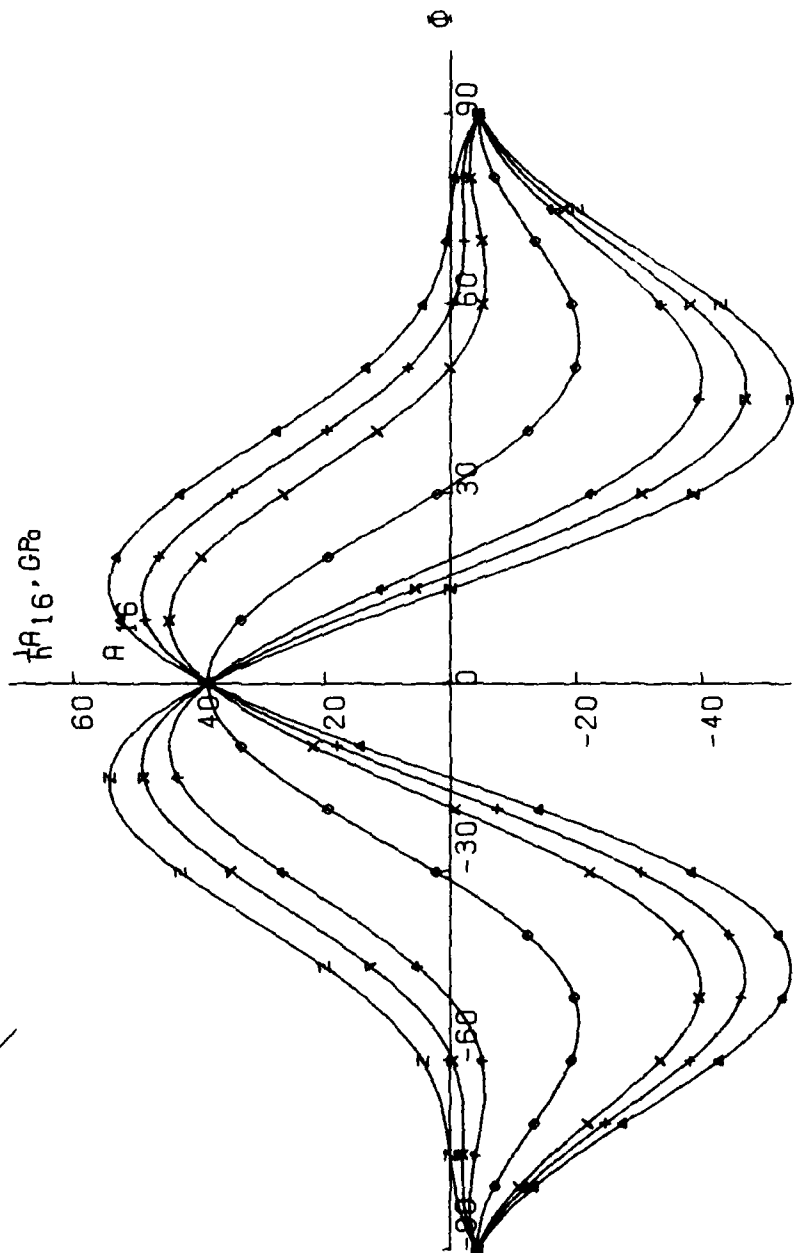
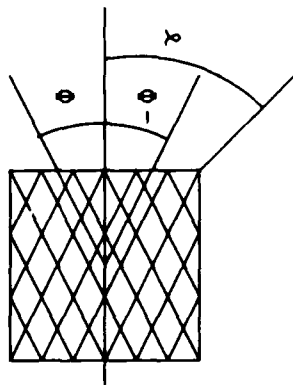


FIG.:71



Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Z (0/1)

$\chi = 30$

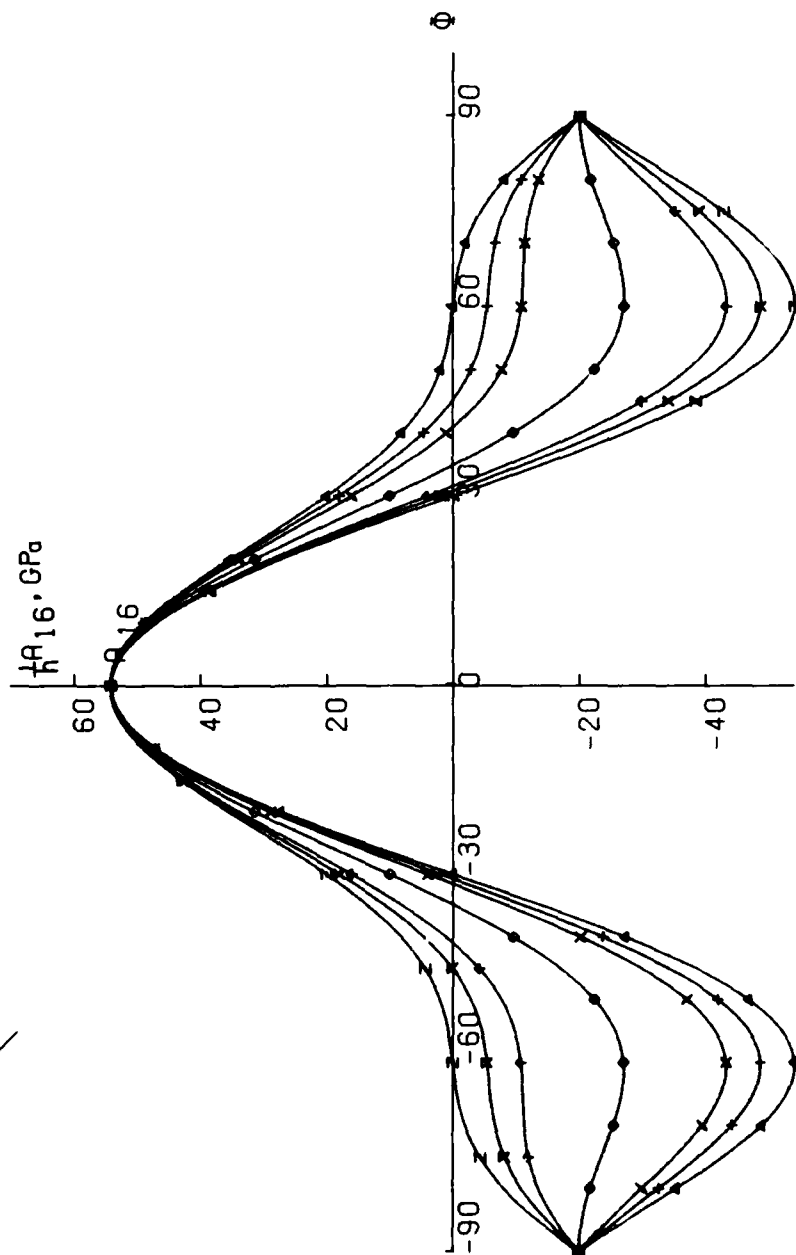
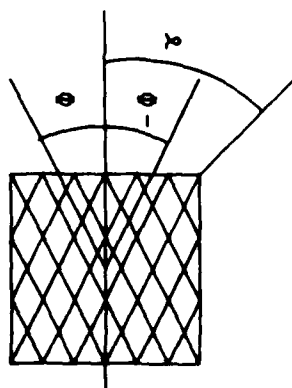


FIG.: 72



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Z (0/1)

$\gamma = 45$

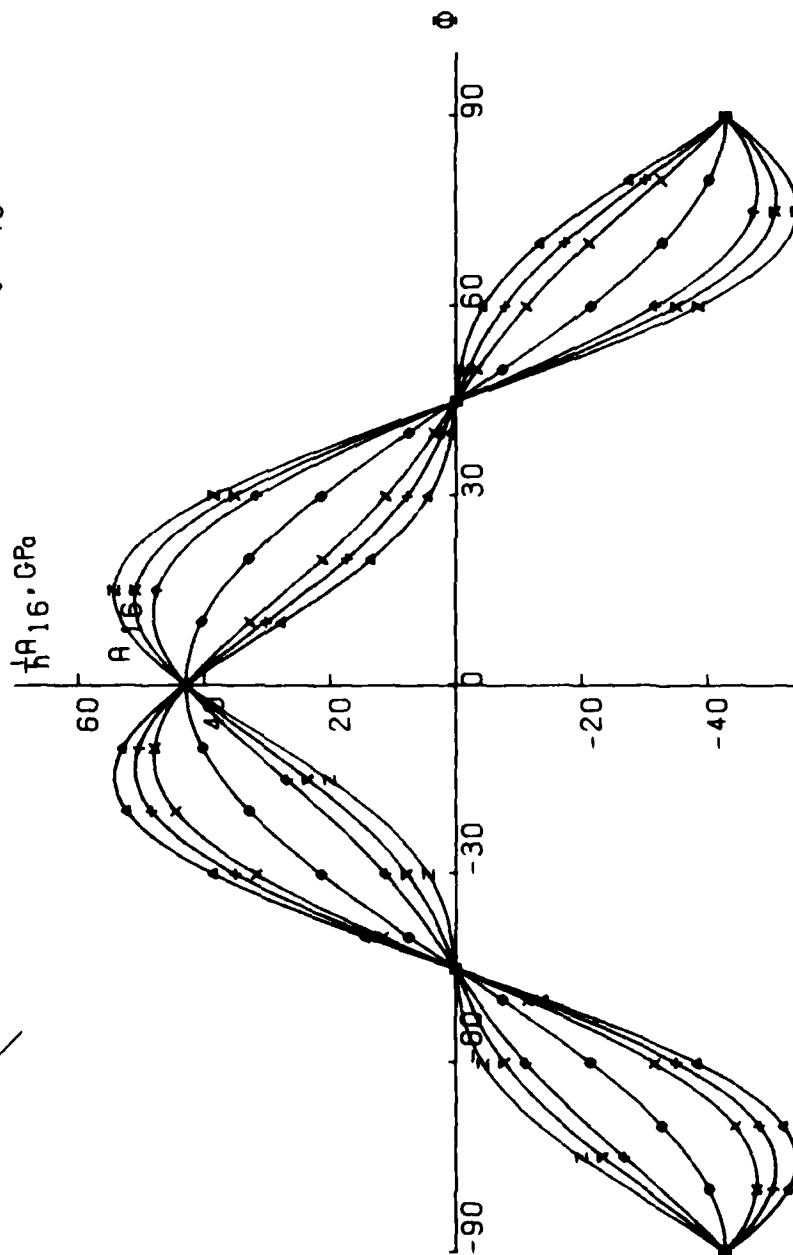
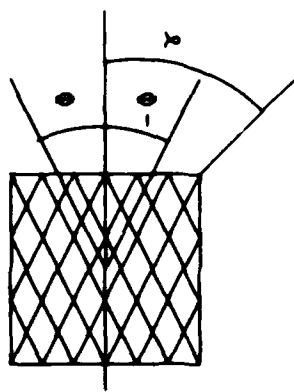


FIG.: 73



101

Φ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \blacklozenge (1/4)
 \times (1/9)
 Σ (0/1)
 $\gamma = 60$

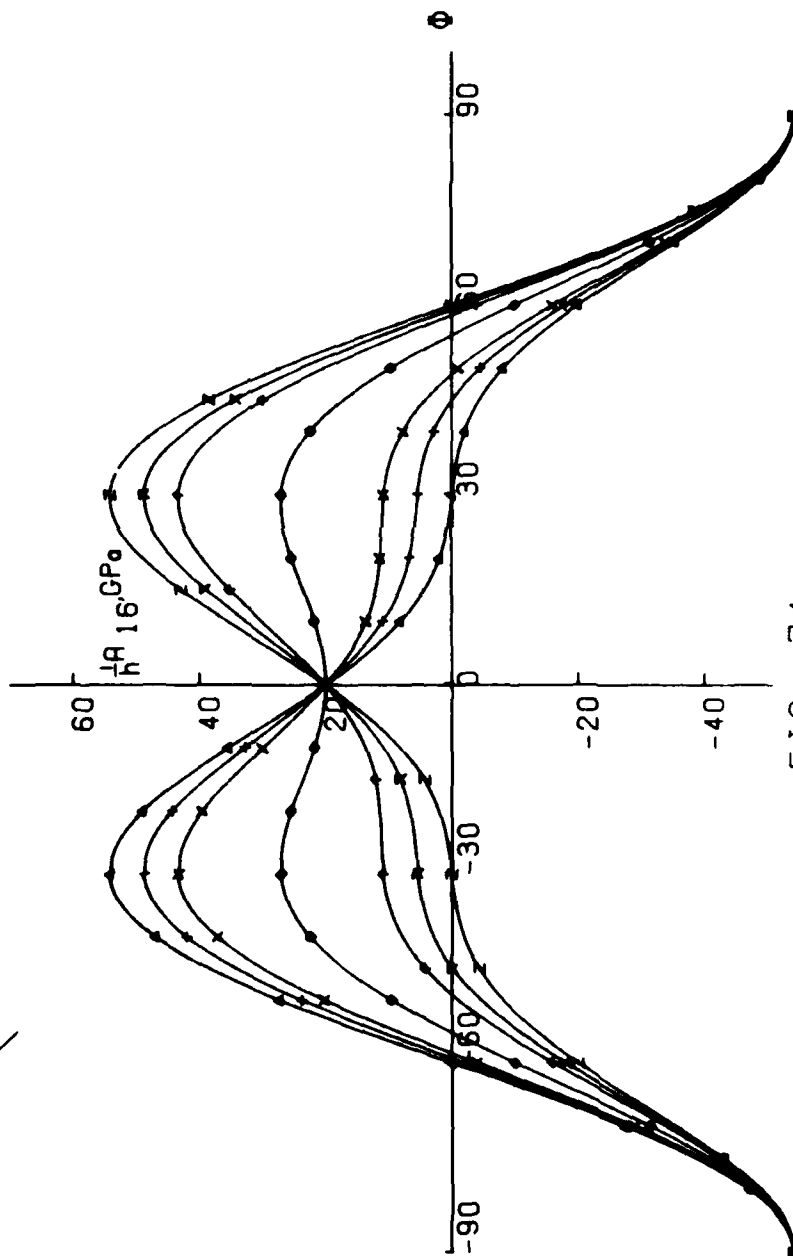
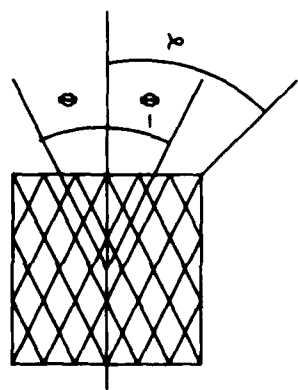


FIG.: 74



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Z (0/1)
 $\chi = 75$

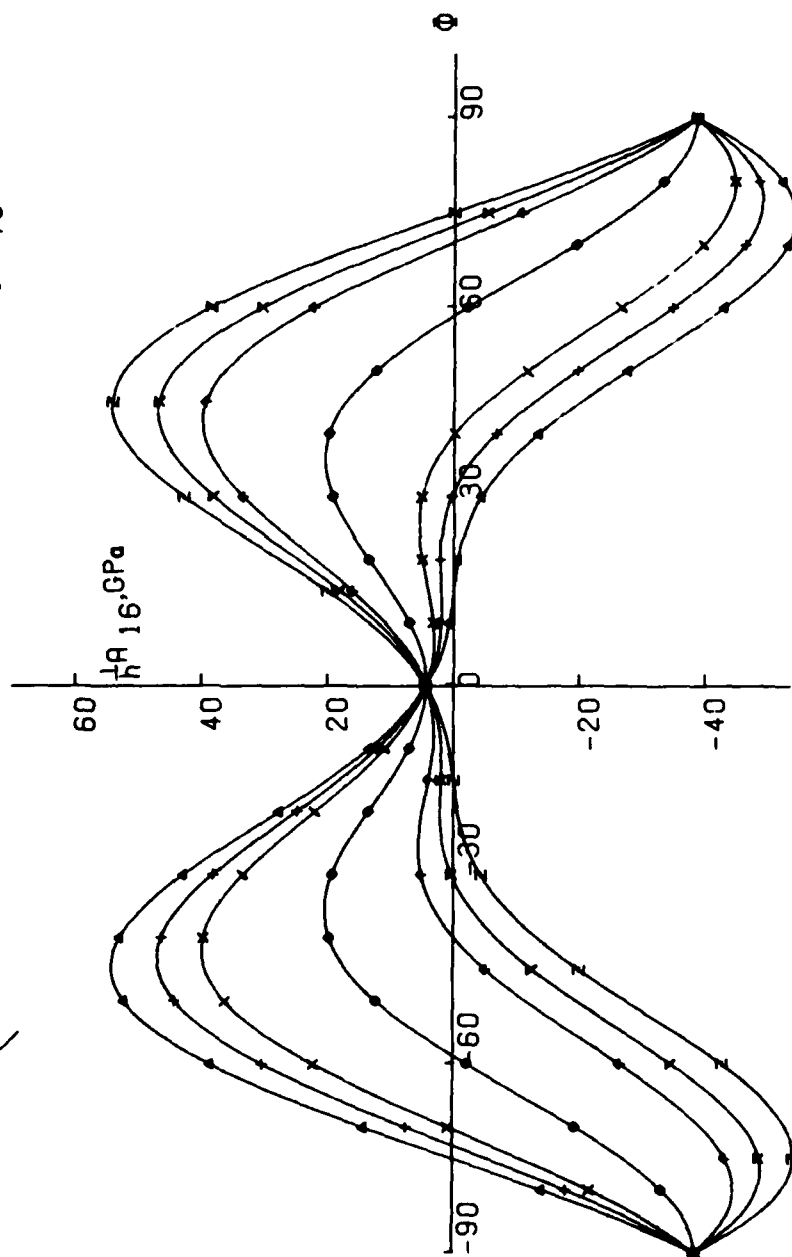
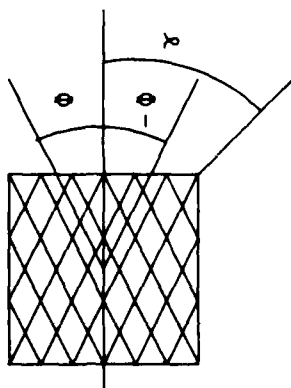


FIG.: 75



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 \square (0/1)

$\phi = 15$

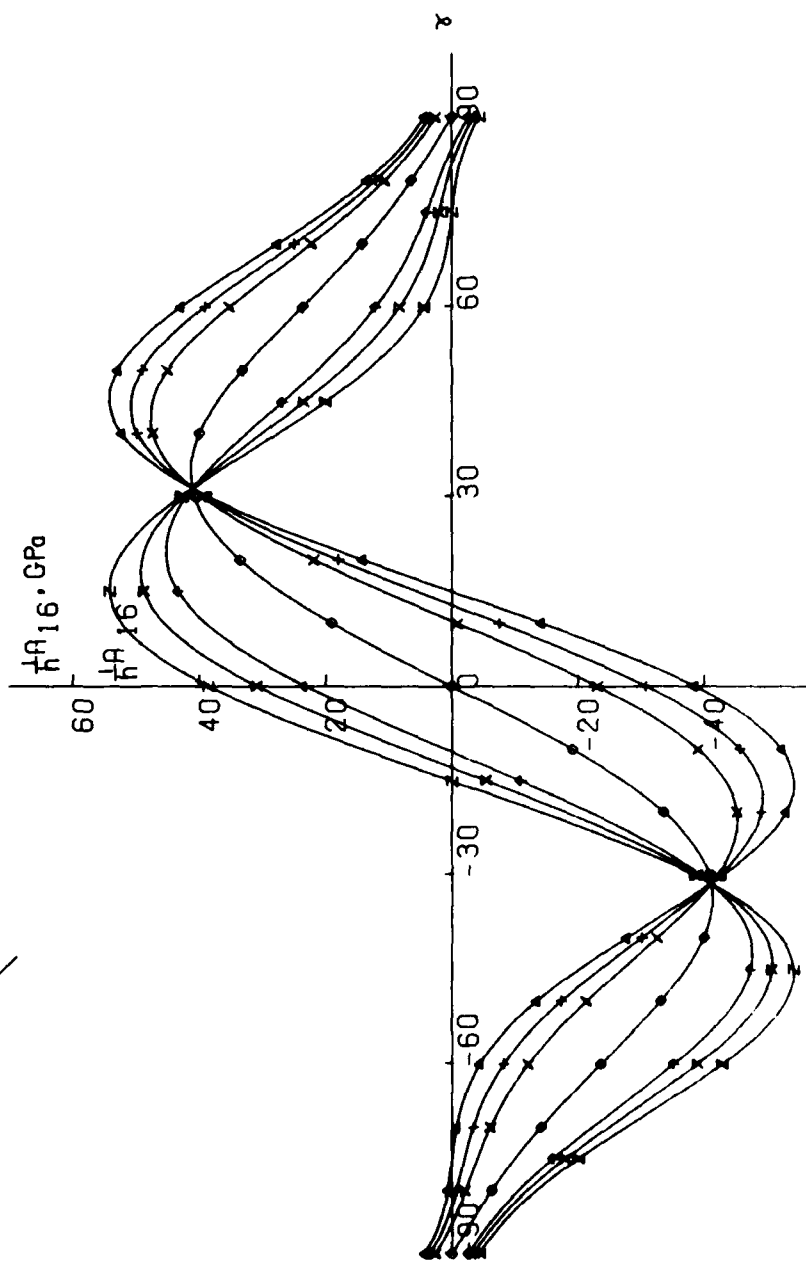
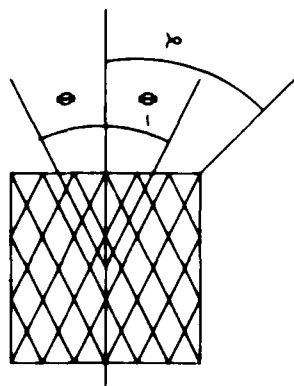


FIG.:76



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \blacktriangle (1/4)
 \times (1/9)
 Z (0/1)
 $\phi = 30$

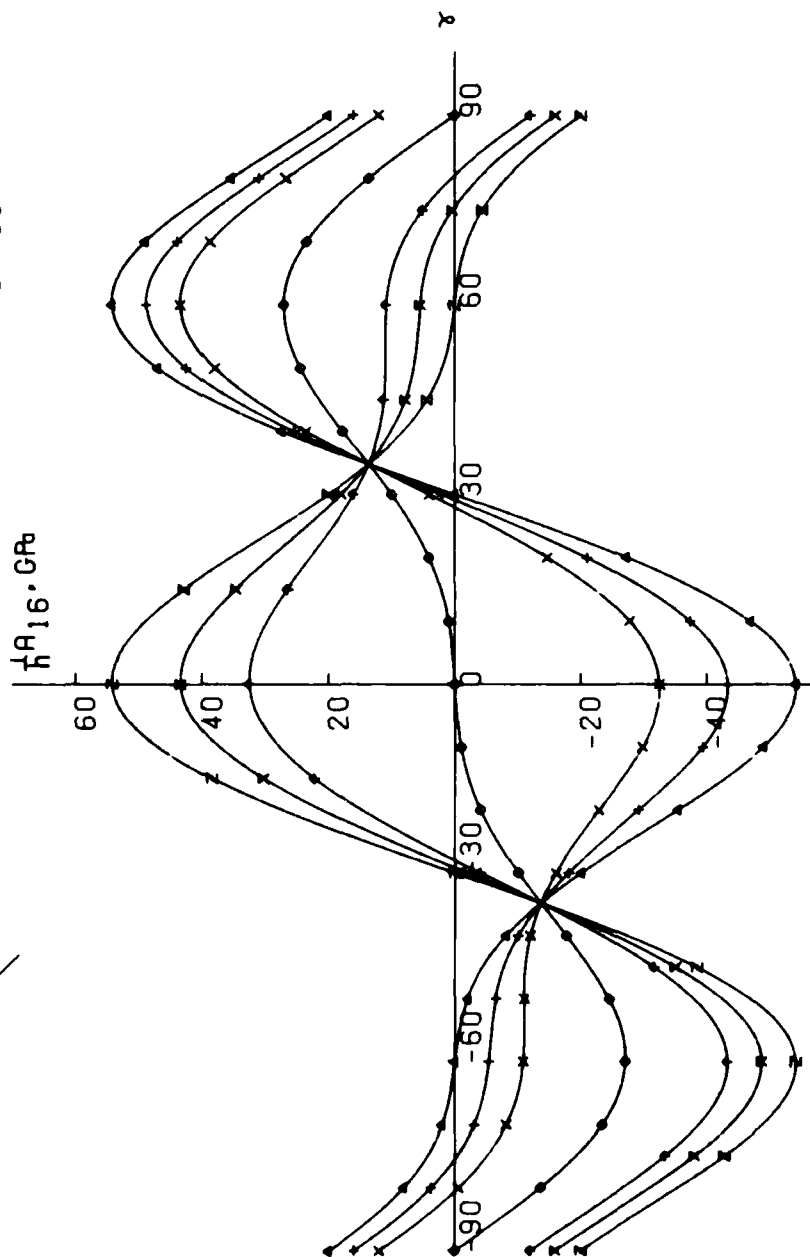
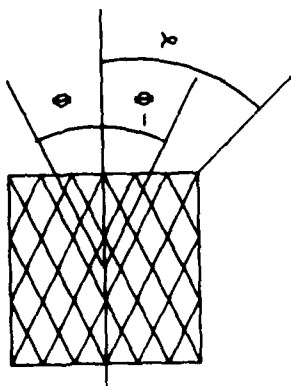


FIG.:77



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\phi = 45$

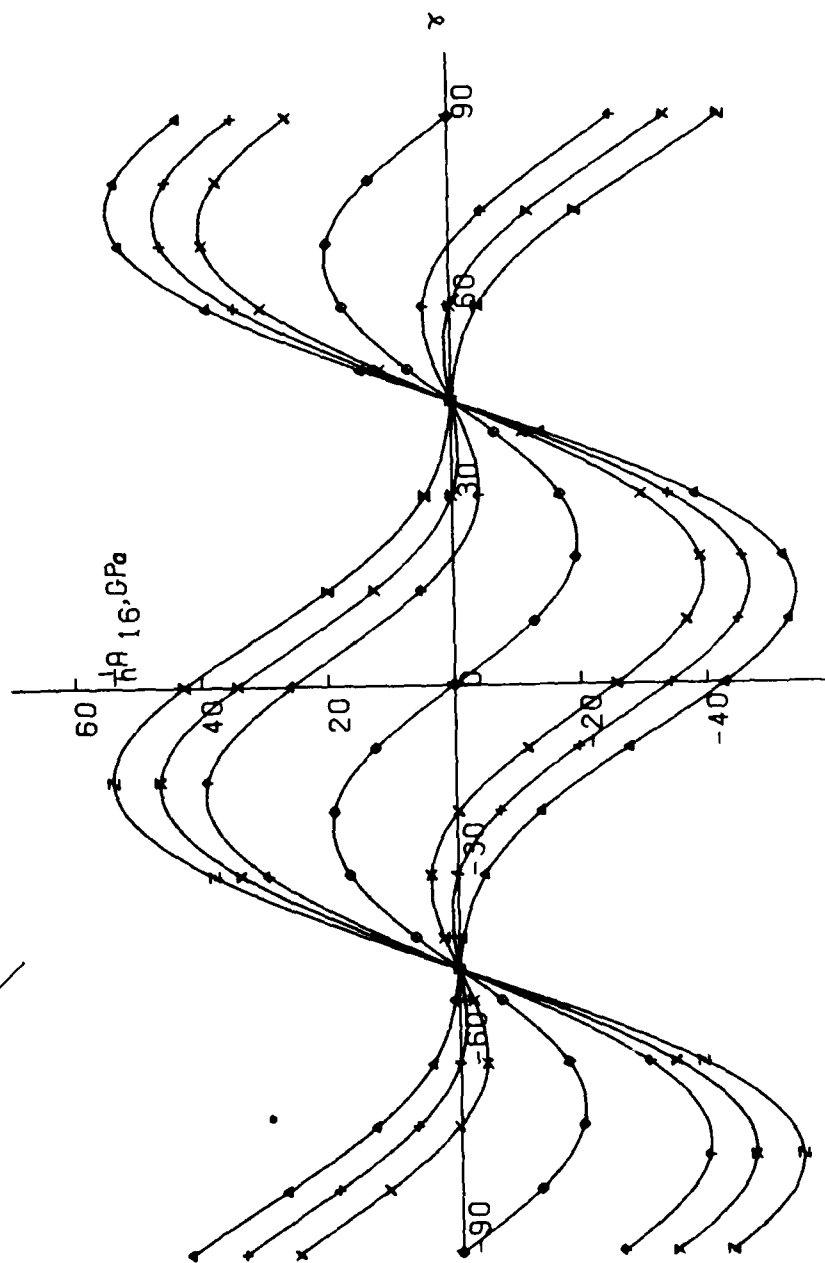
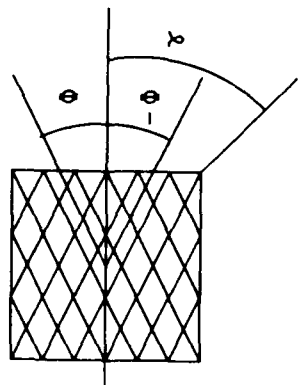


FIG.:78



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)
 $\phi = 60$

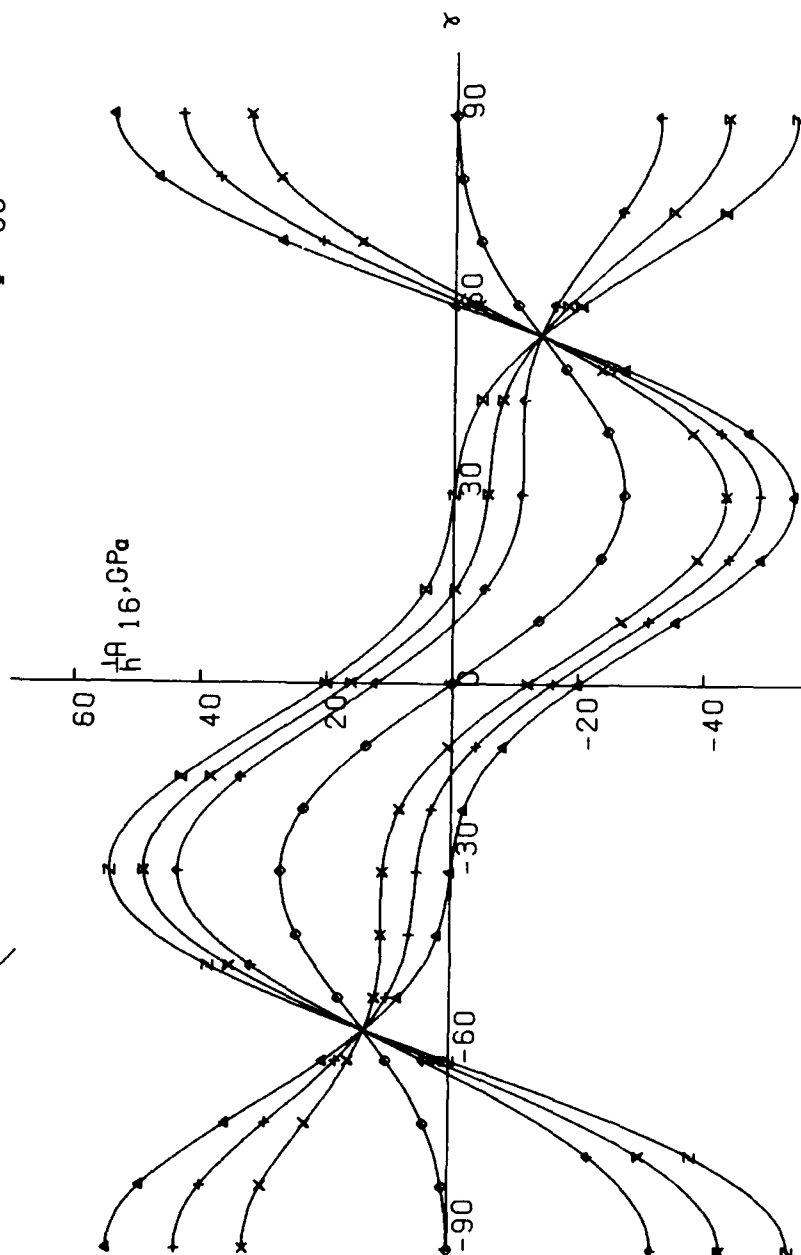


FIG.: 79

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\Phi = 75$

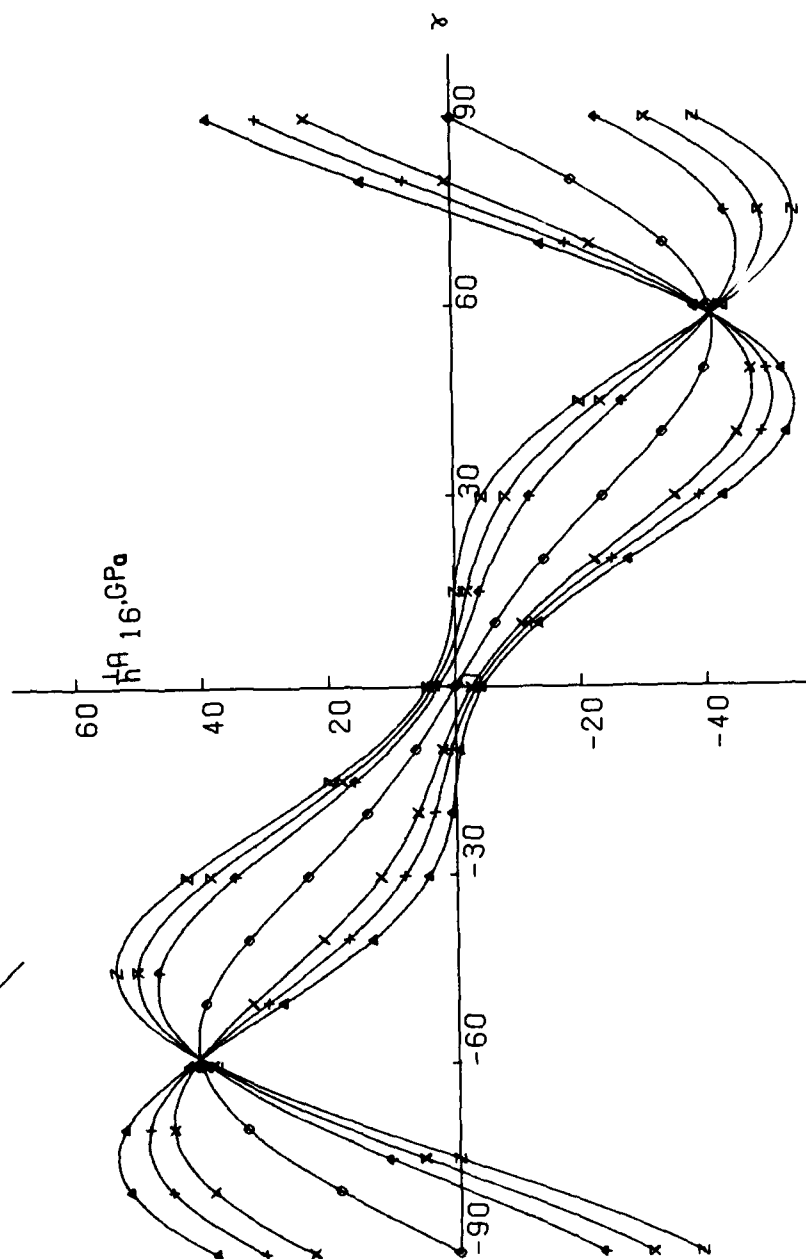
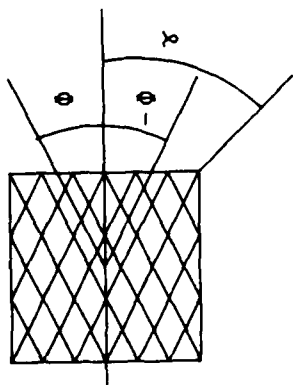
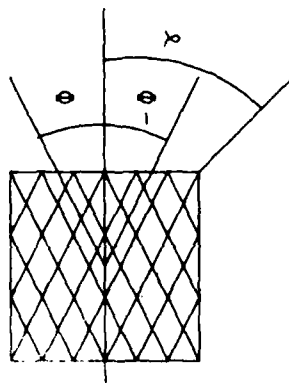


FIG.: 80



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = -75$

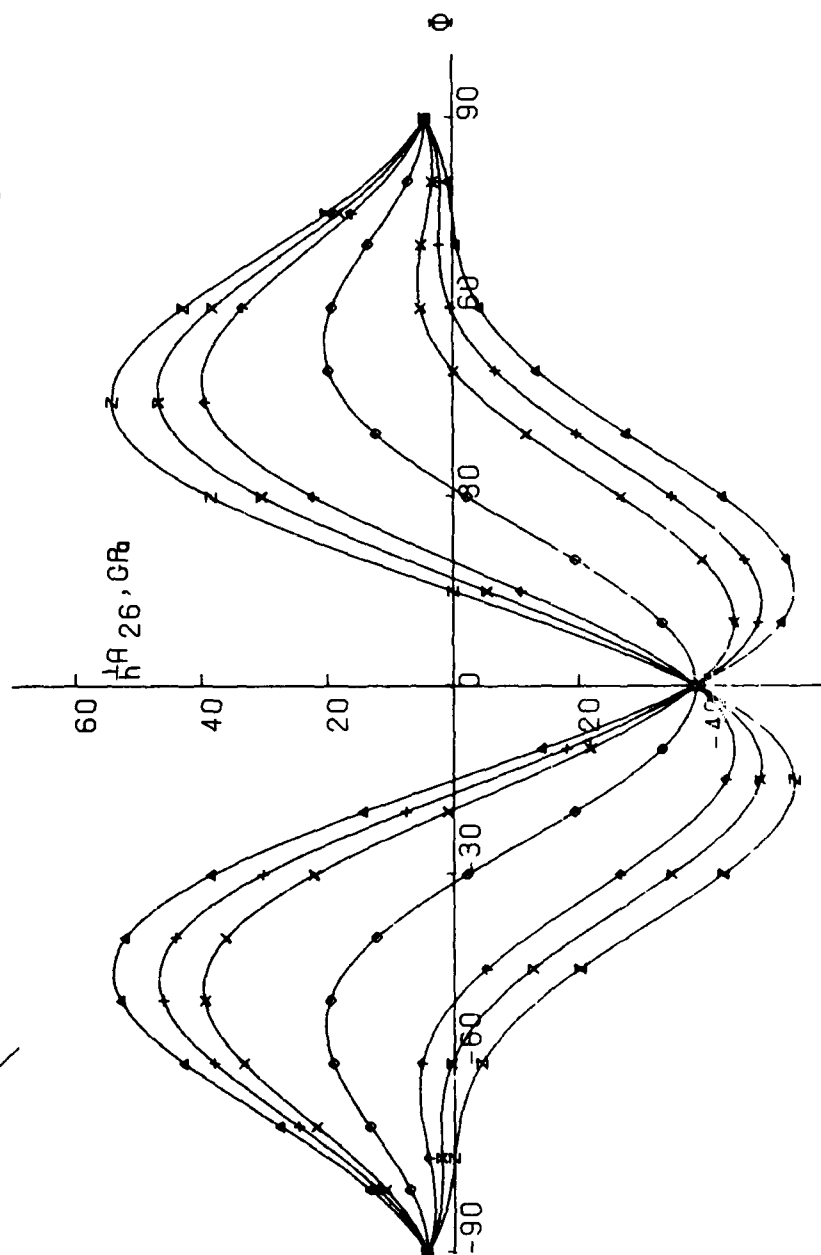
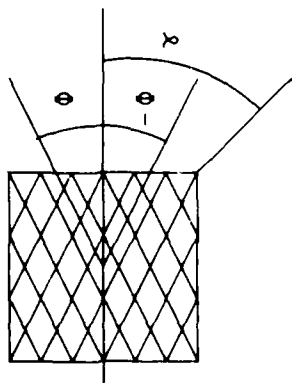


FIG.:81



Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Z (0/1)

$\chi = -60$

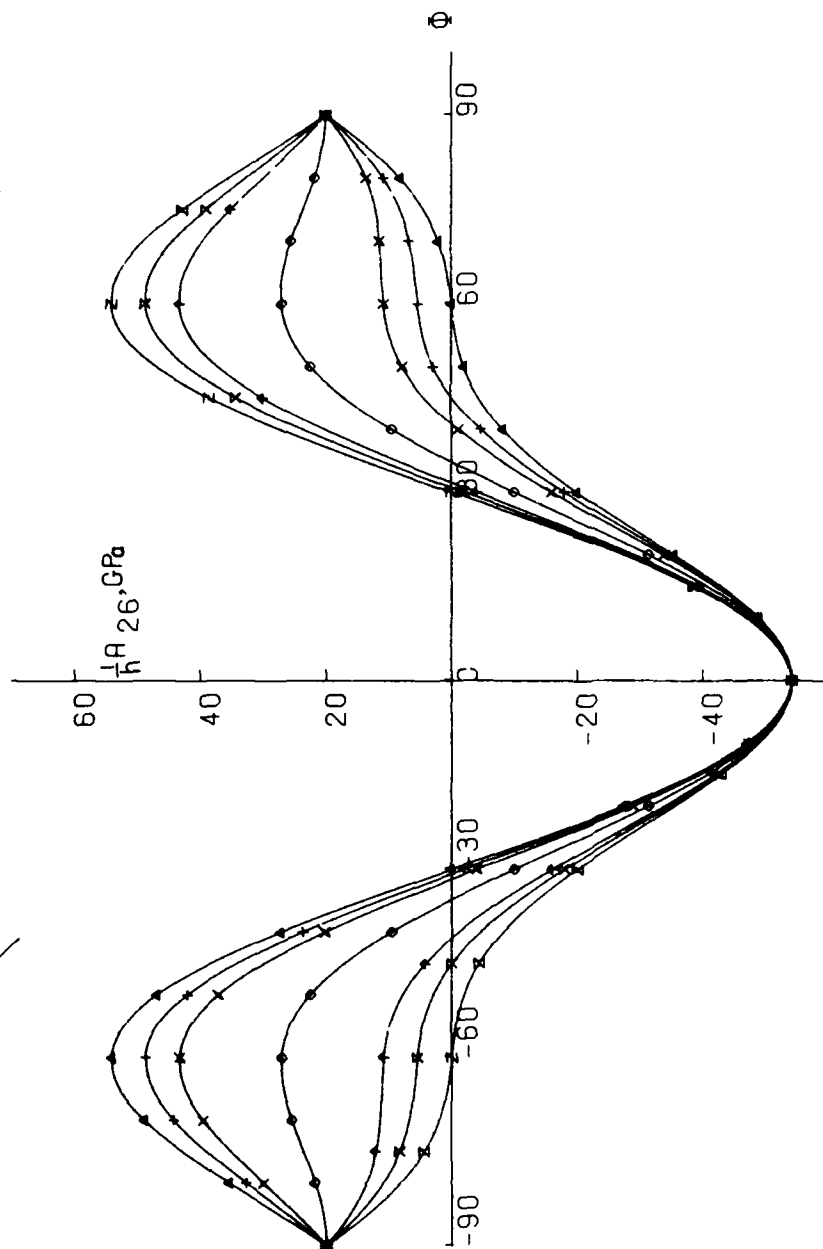
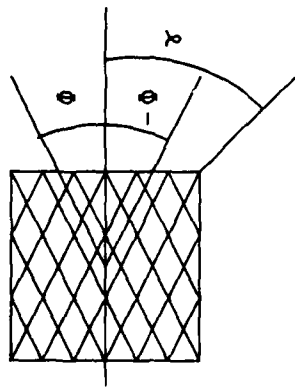


FIG.:82



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Z (0/1)
 $\chi = -45$

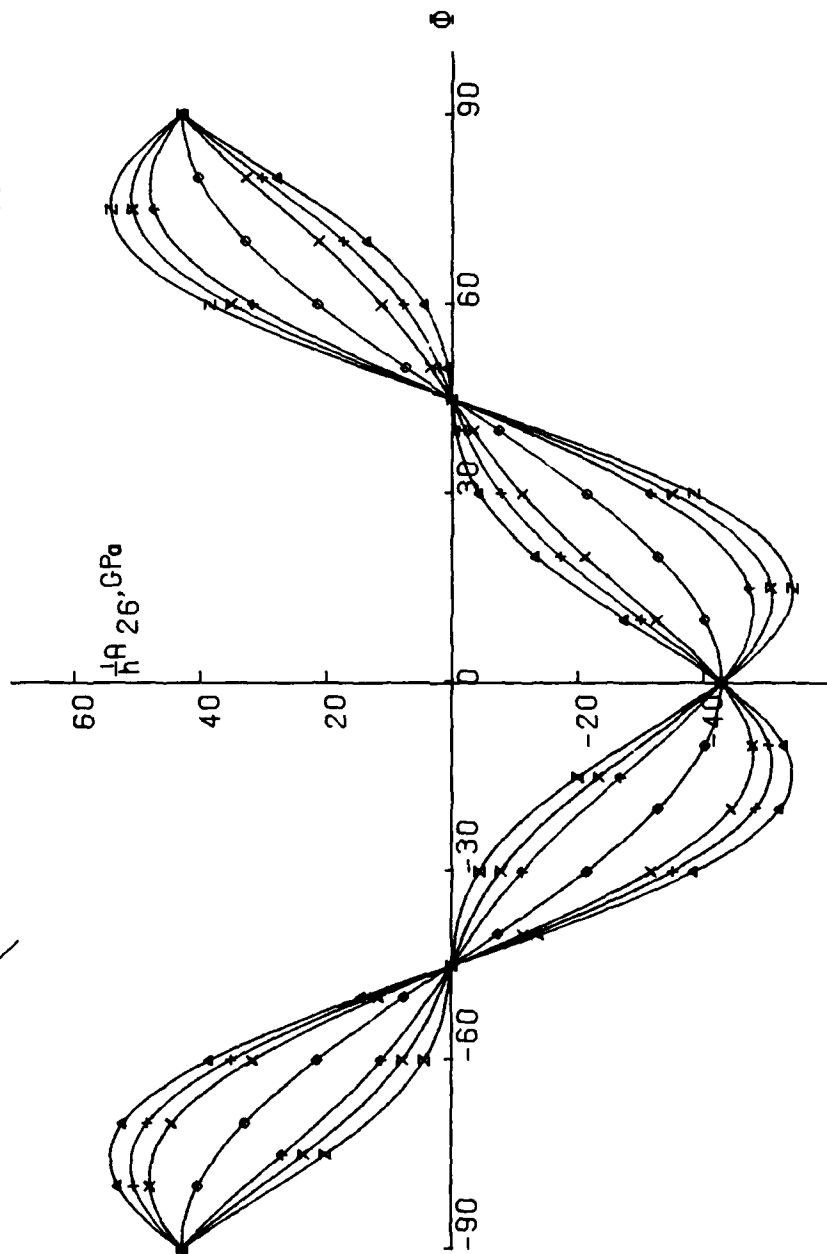
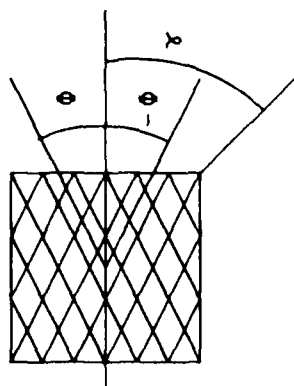


FIG.:83



$\phi / -\phi$

Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
∇	(1/4)
\times	(1/9)
Z	(0/1)

$\gamma = -30$

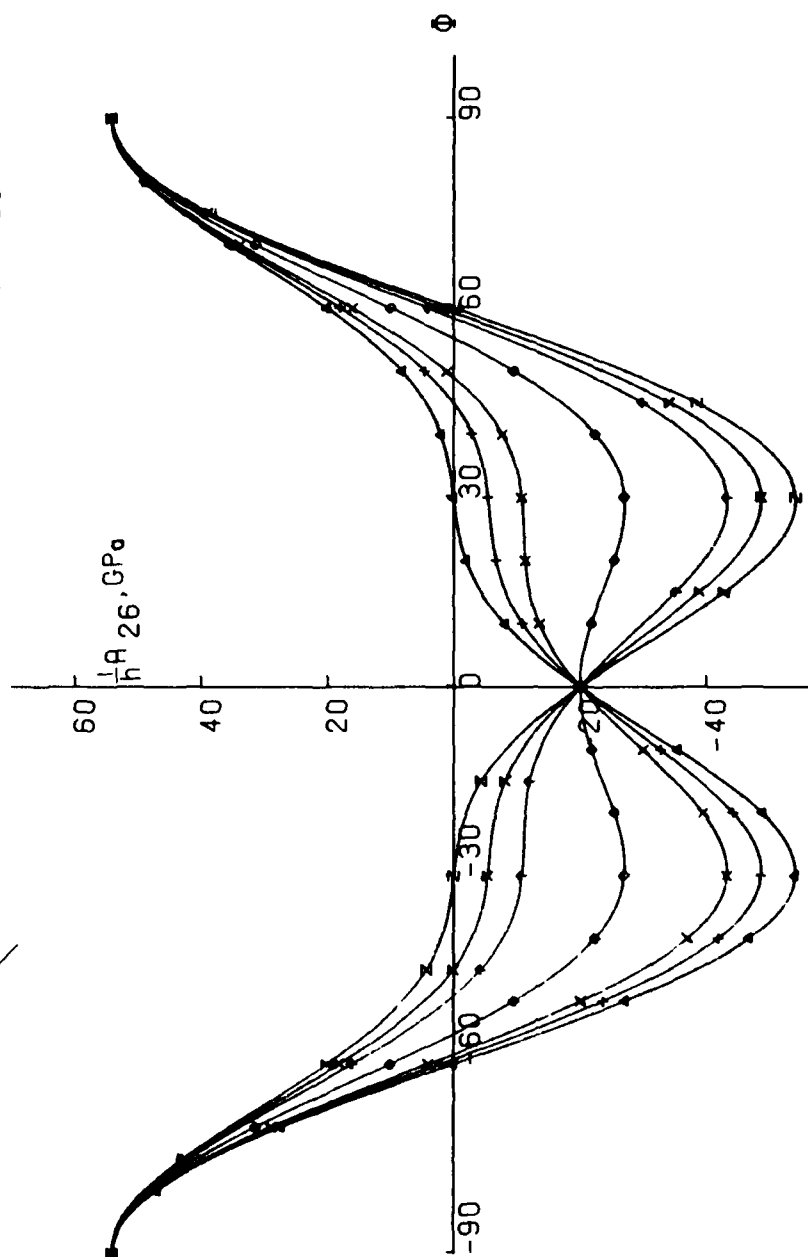
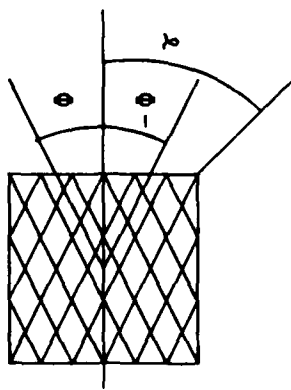


FIG.: 84



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\chi = -15$

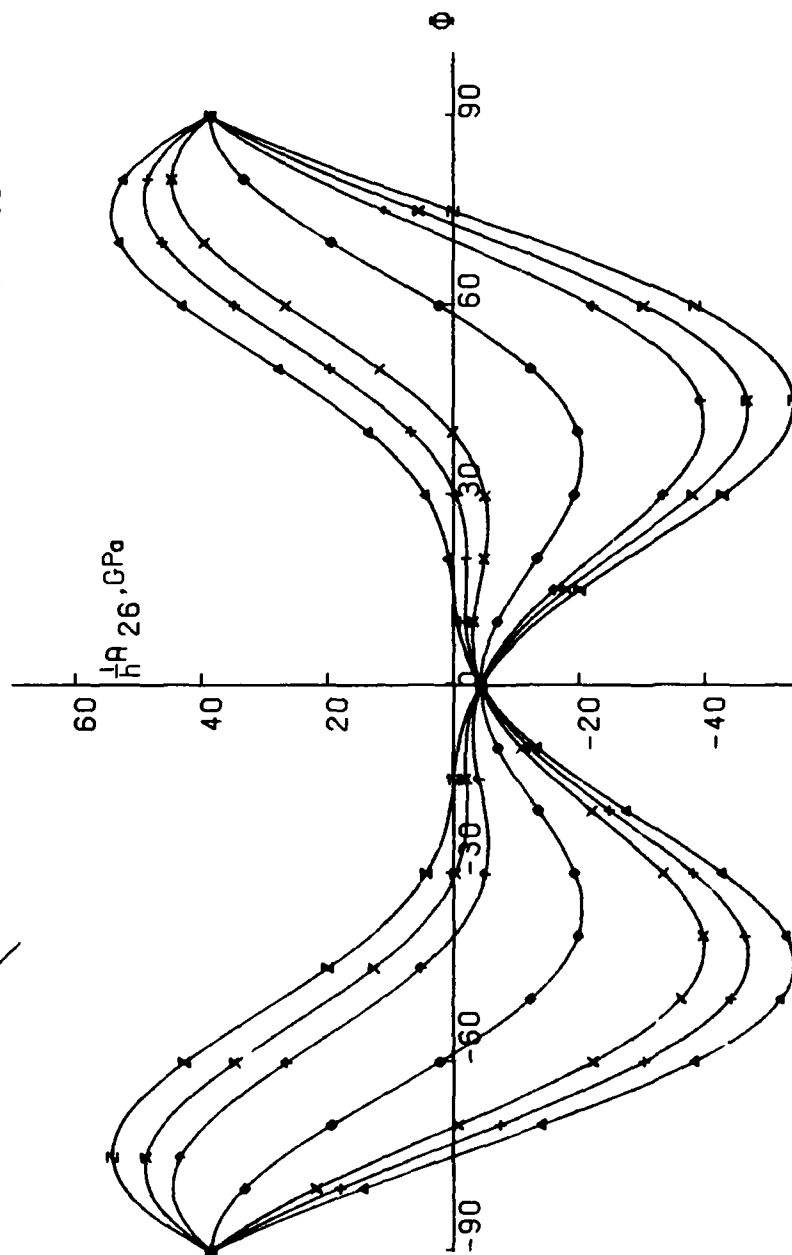


FIG.:85

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Z (0/1)

$\gamma = 0$

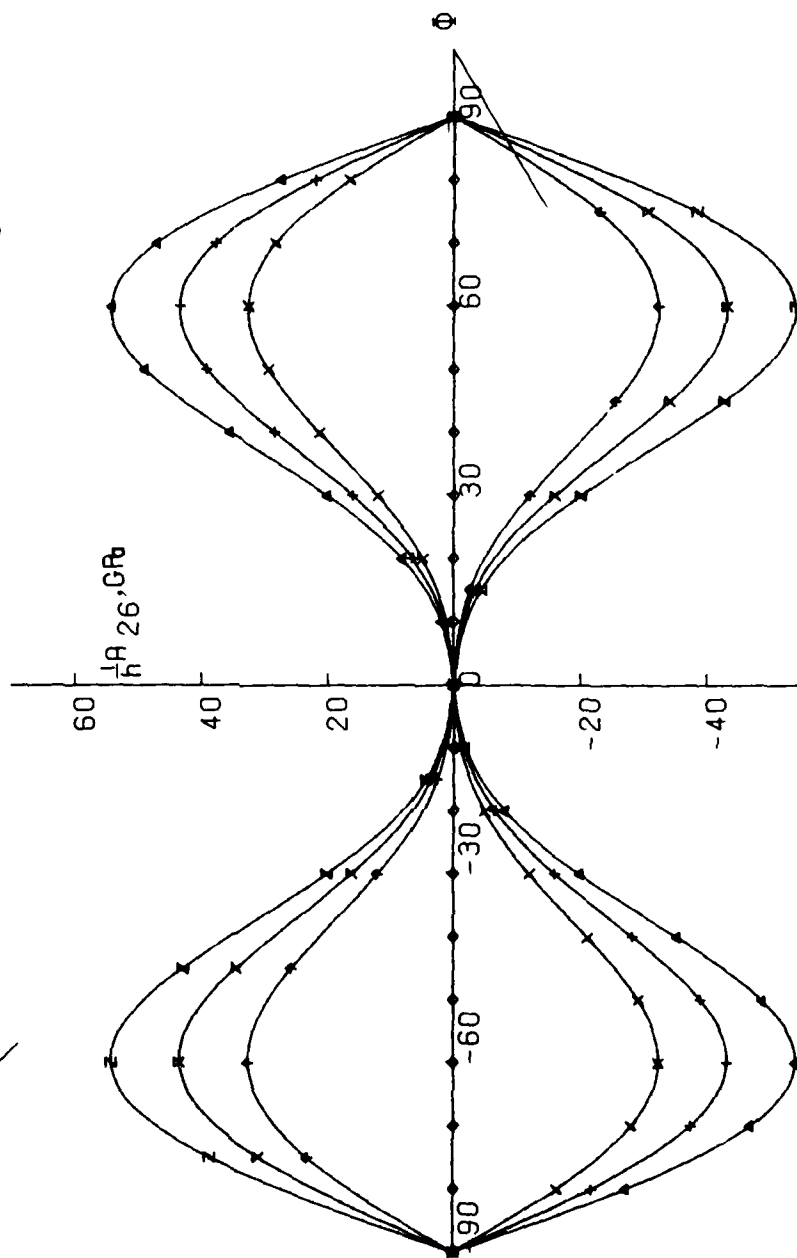
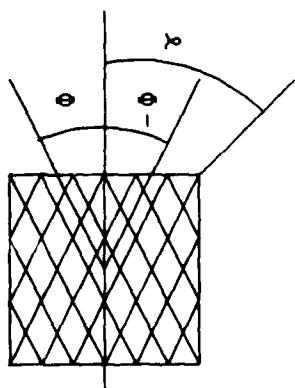
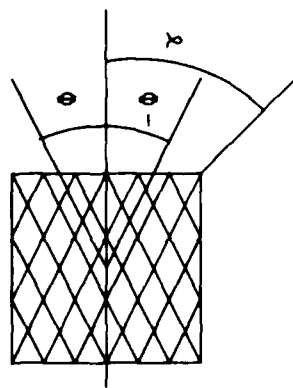


FIG.:86



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 \times (1/9)
 Z (0/1)
 $\gamma = 15$

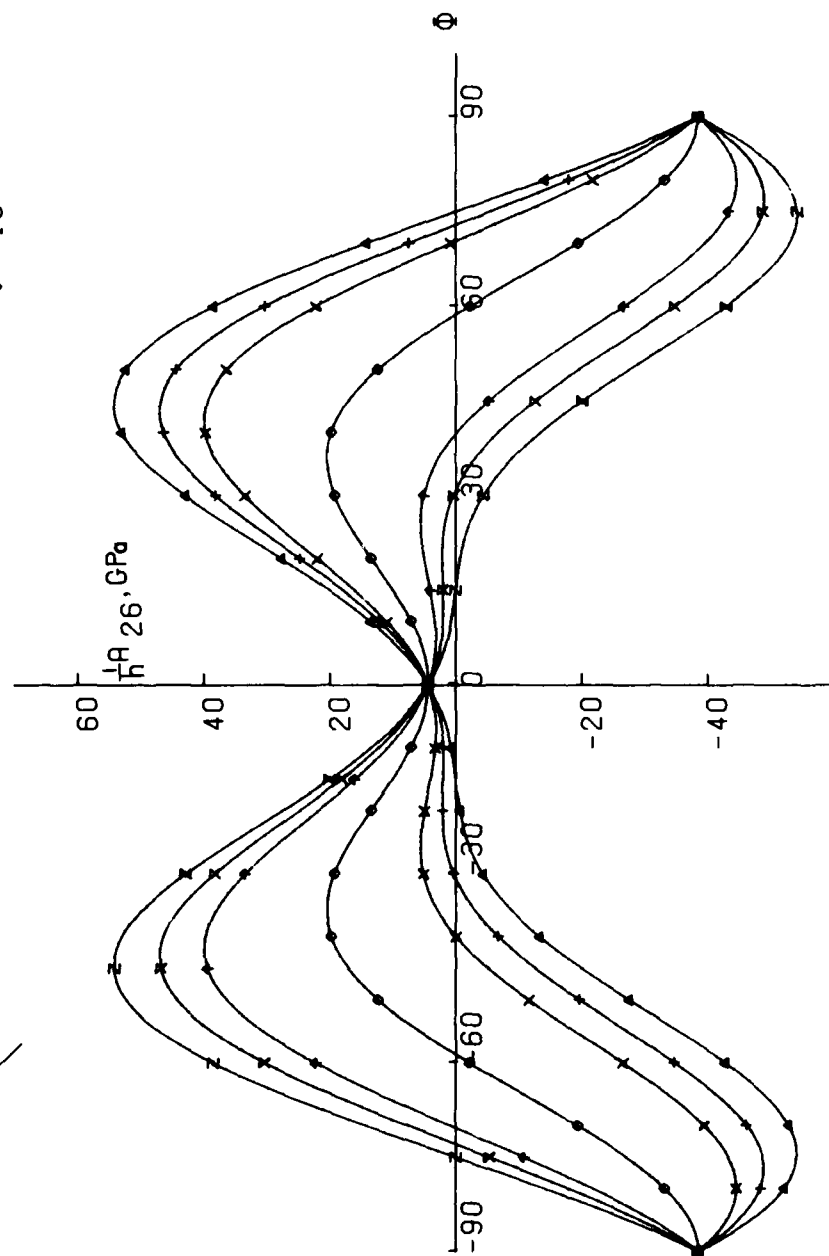
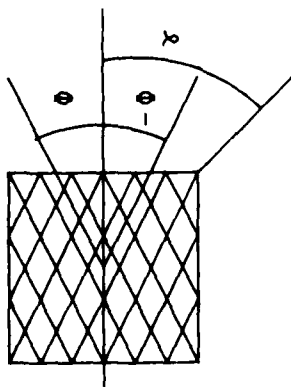


FIG.: 87



ϕ/ϕ

Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
∇	(1/4)
\times	(1/9)
Z	(0/1)

$\gamma = 30$

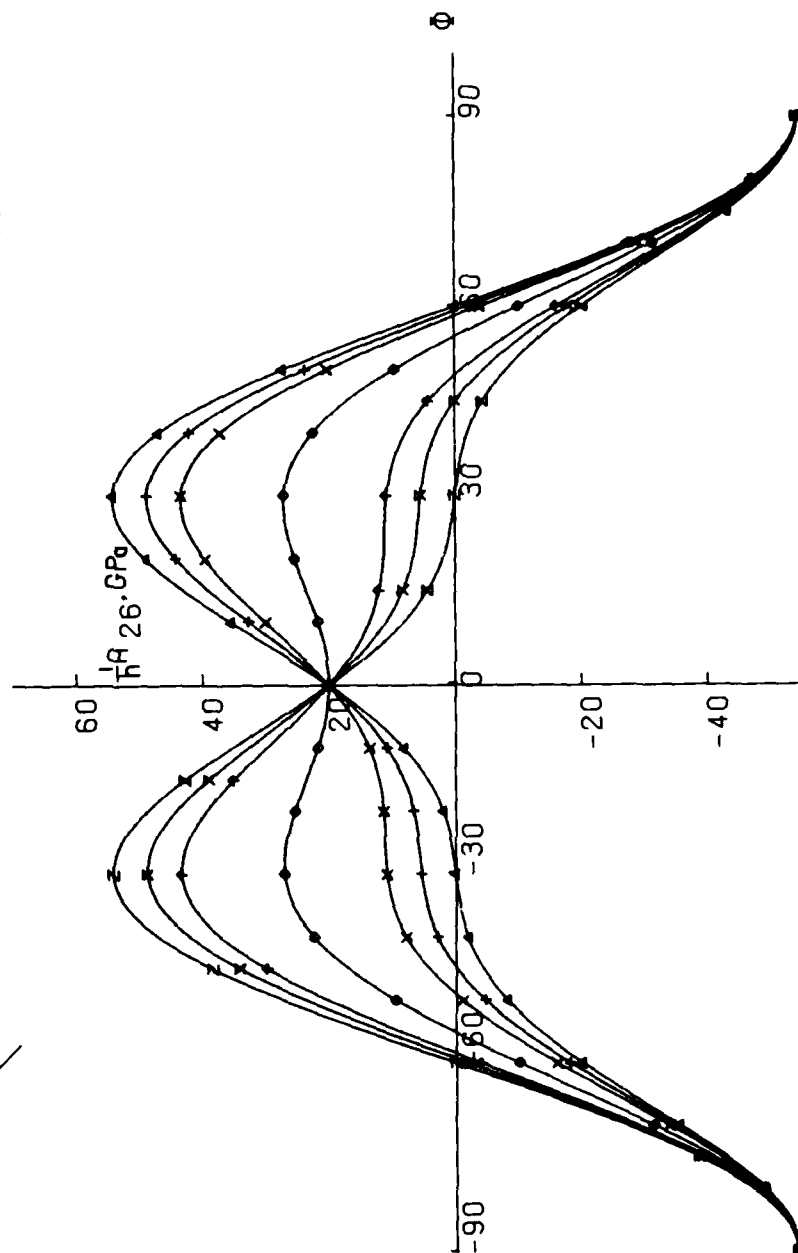
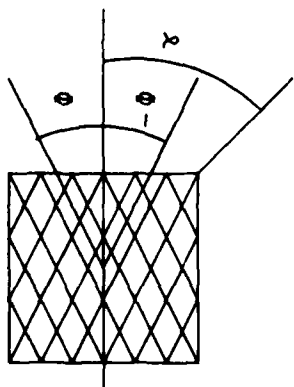


FIG.:88



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 ∇ (0/1)

$\gamma = 45$

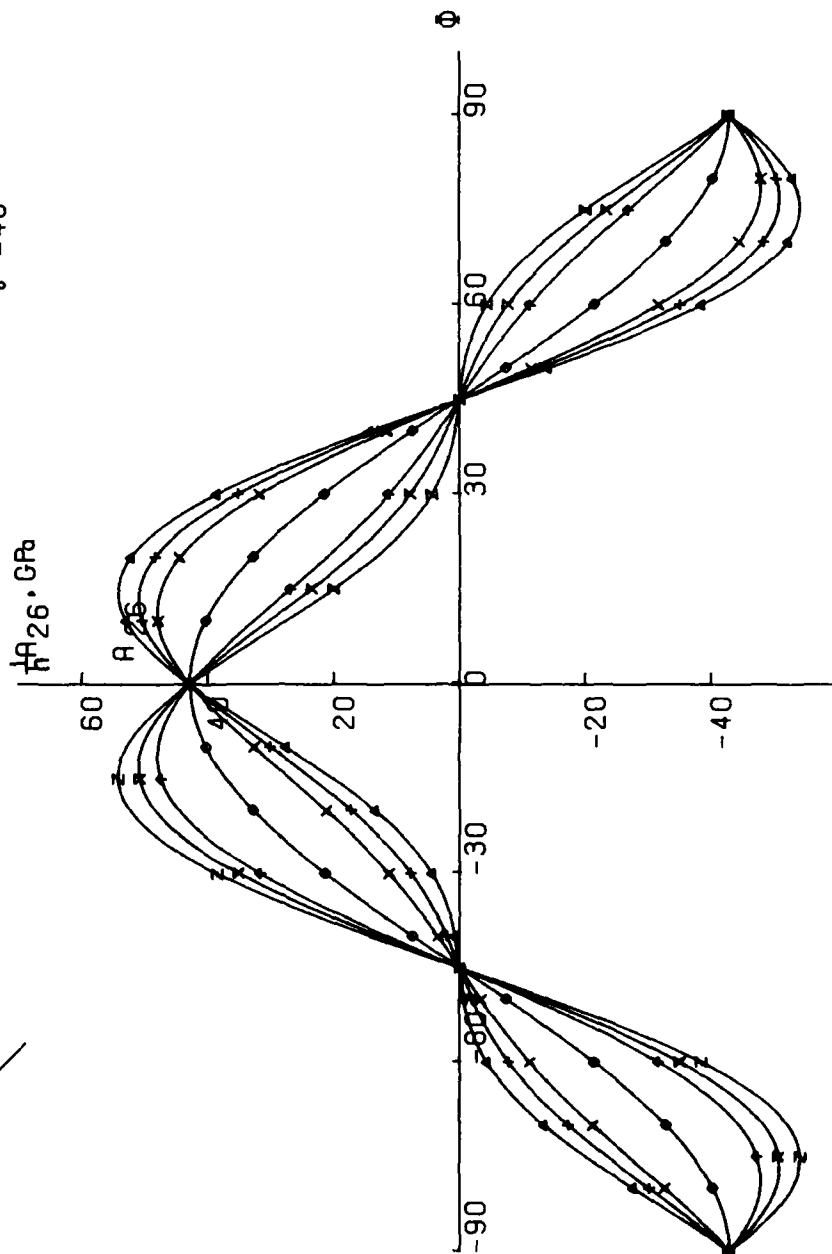
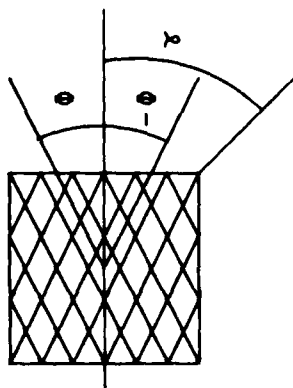


FIG.: 89



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \clubsuit (1/4)
 \bowtie (1/9)
 Σ (0/1)

$\gamma = 60$

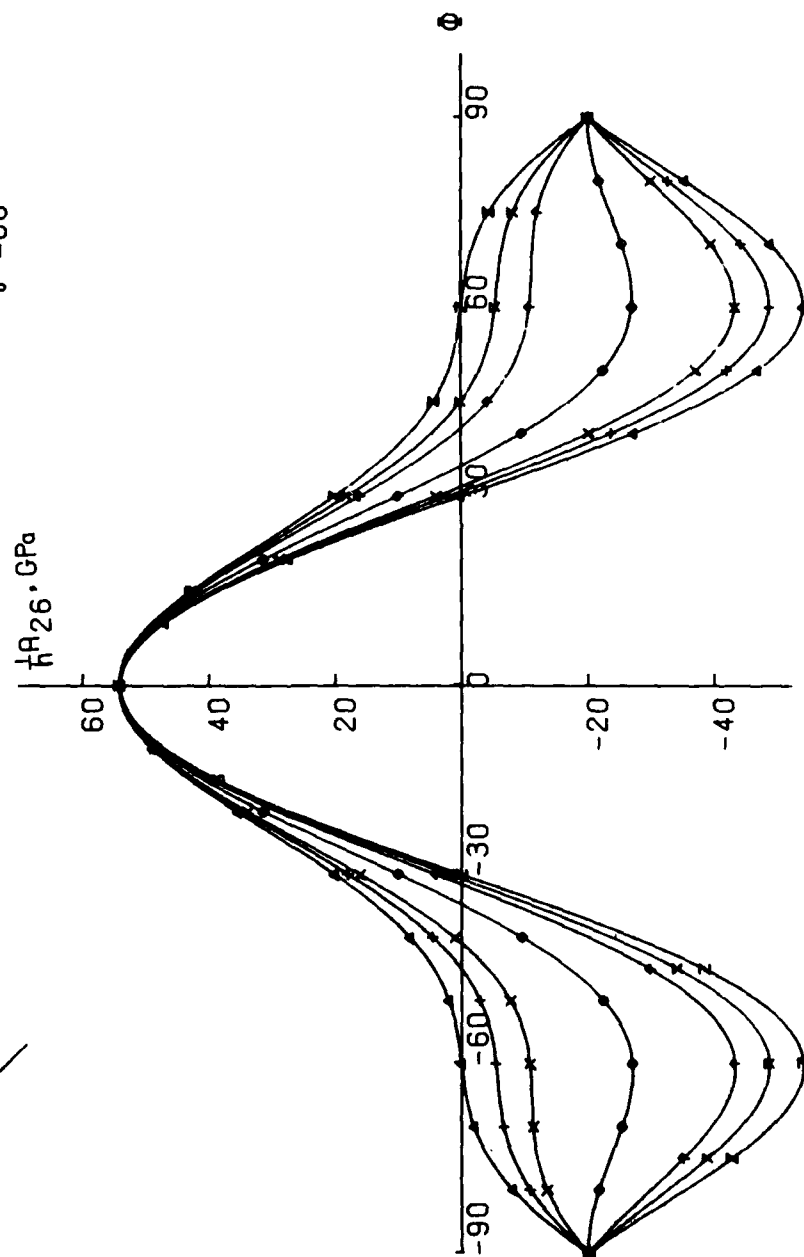
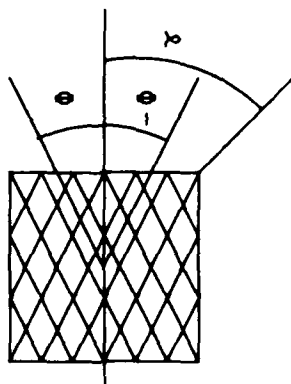


FIG. 90



Φ/Φ

Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
∇	(1/4)
\times	(1/9)
Z	(0/1)

$\chi = 75$

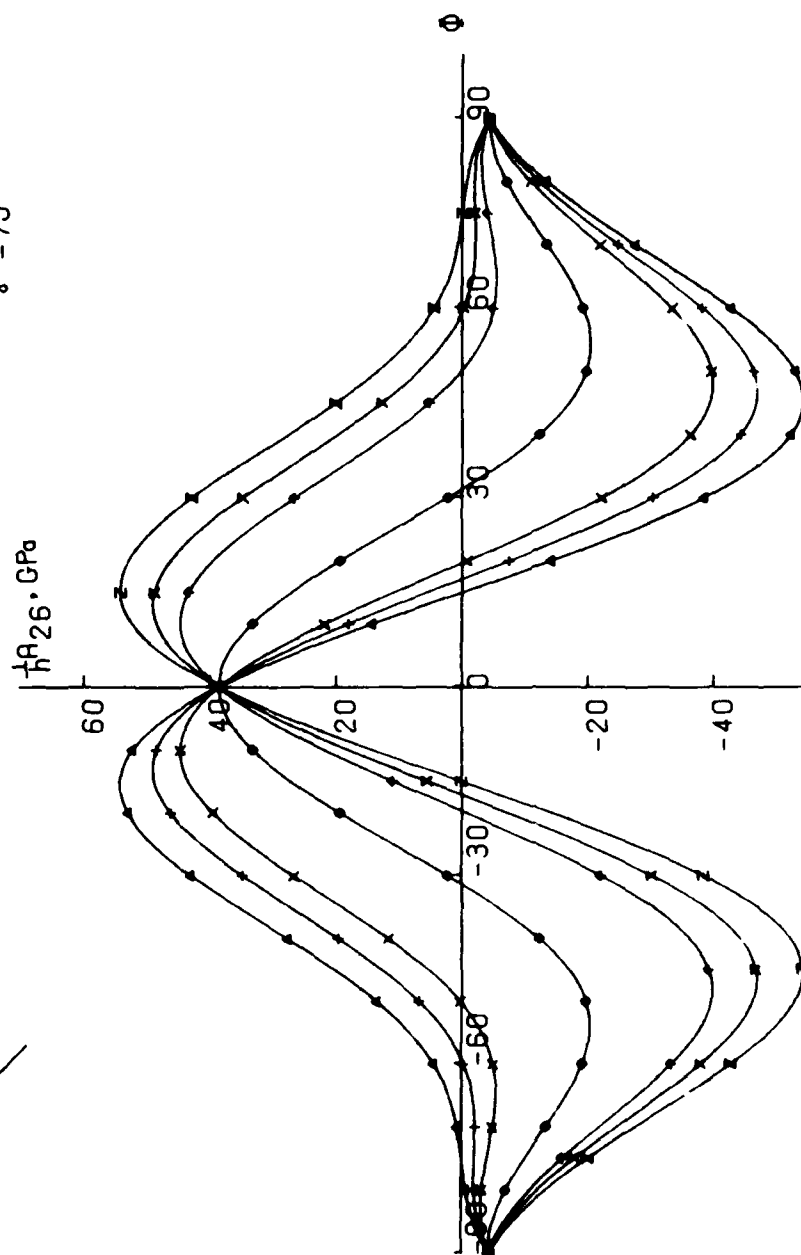


FIG.: 91

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\Phi = 15$

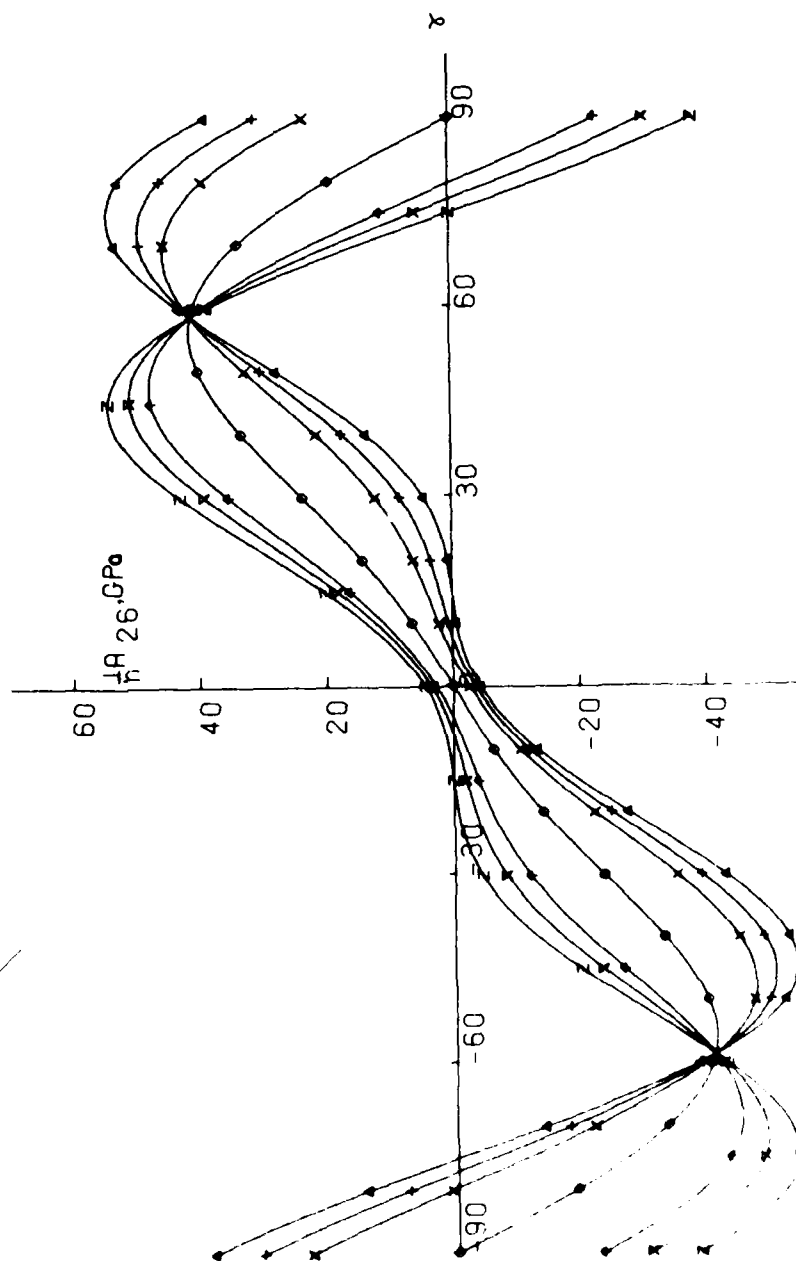
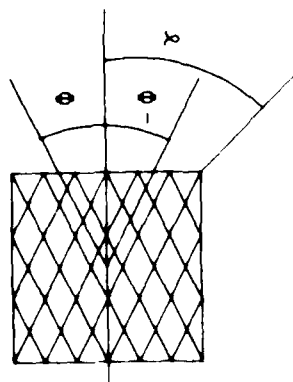
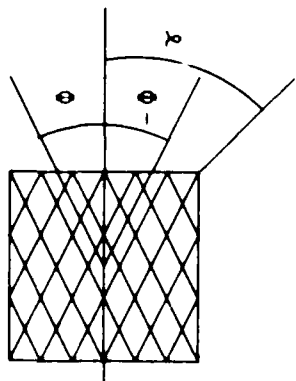


FIG.: 92



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 ∇ (0/1)
 $\phi = 30$

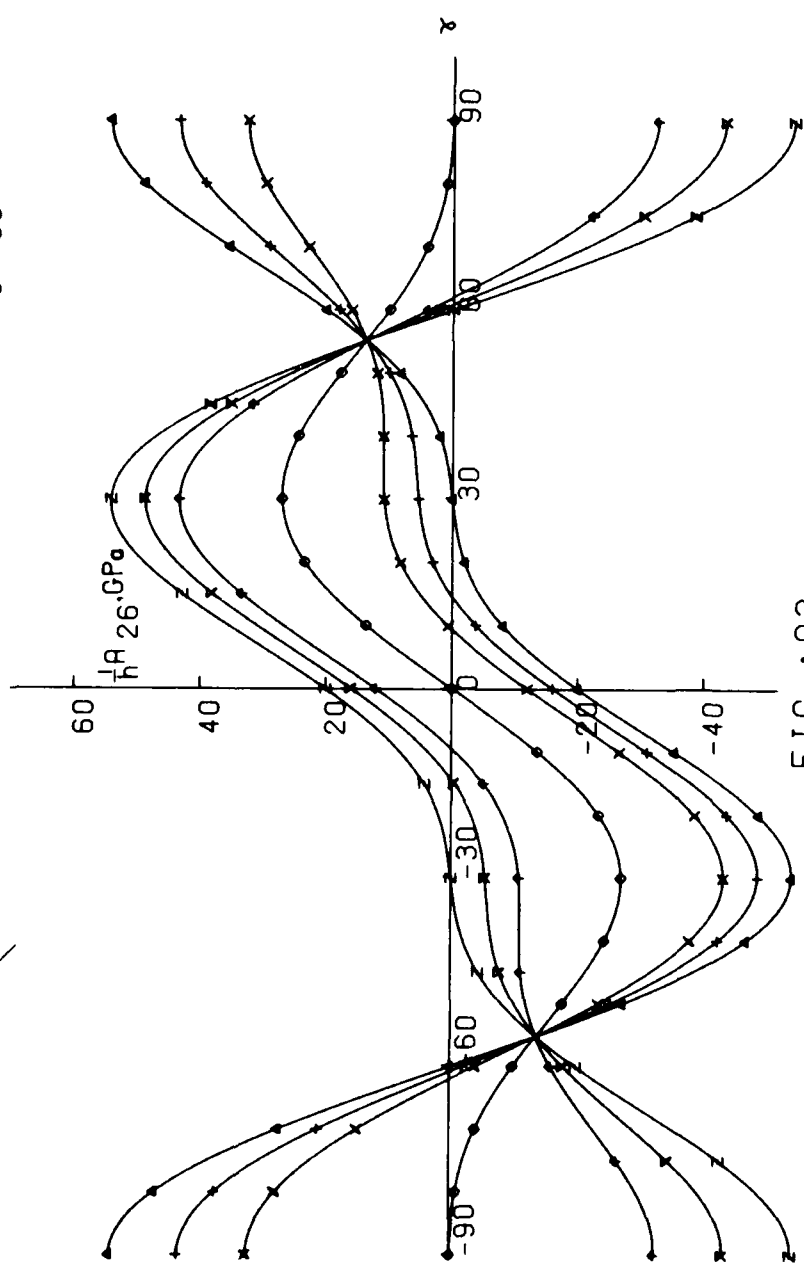
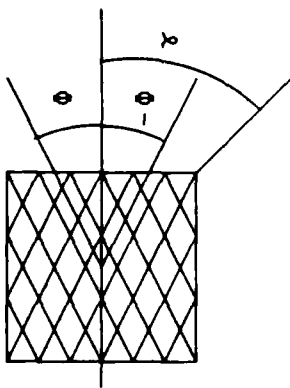


FIG.:93



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\phi = 45$

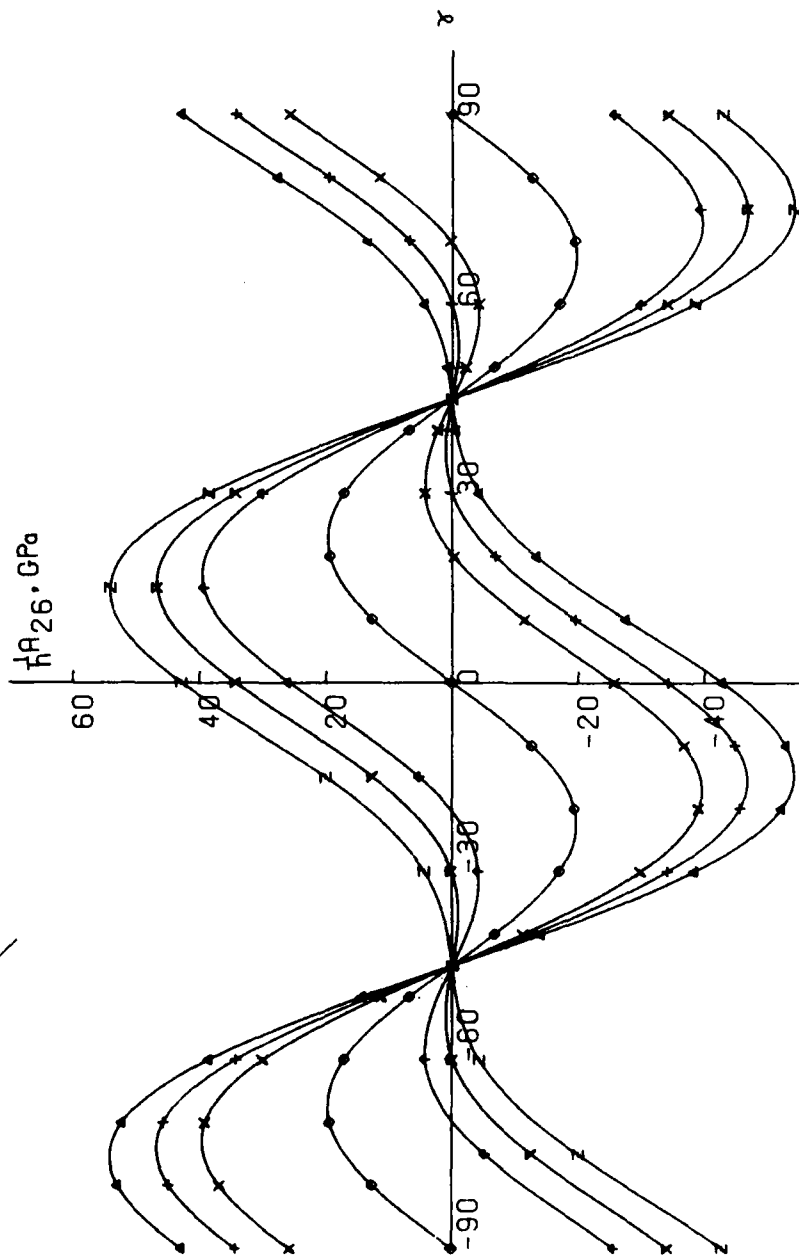
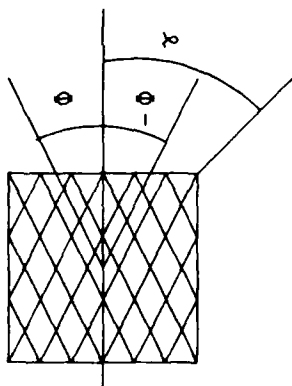


FIG.: 94



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 z (0/1)
 $\phi = 60$

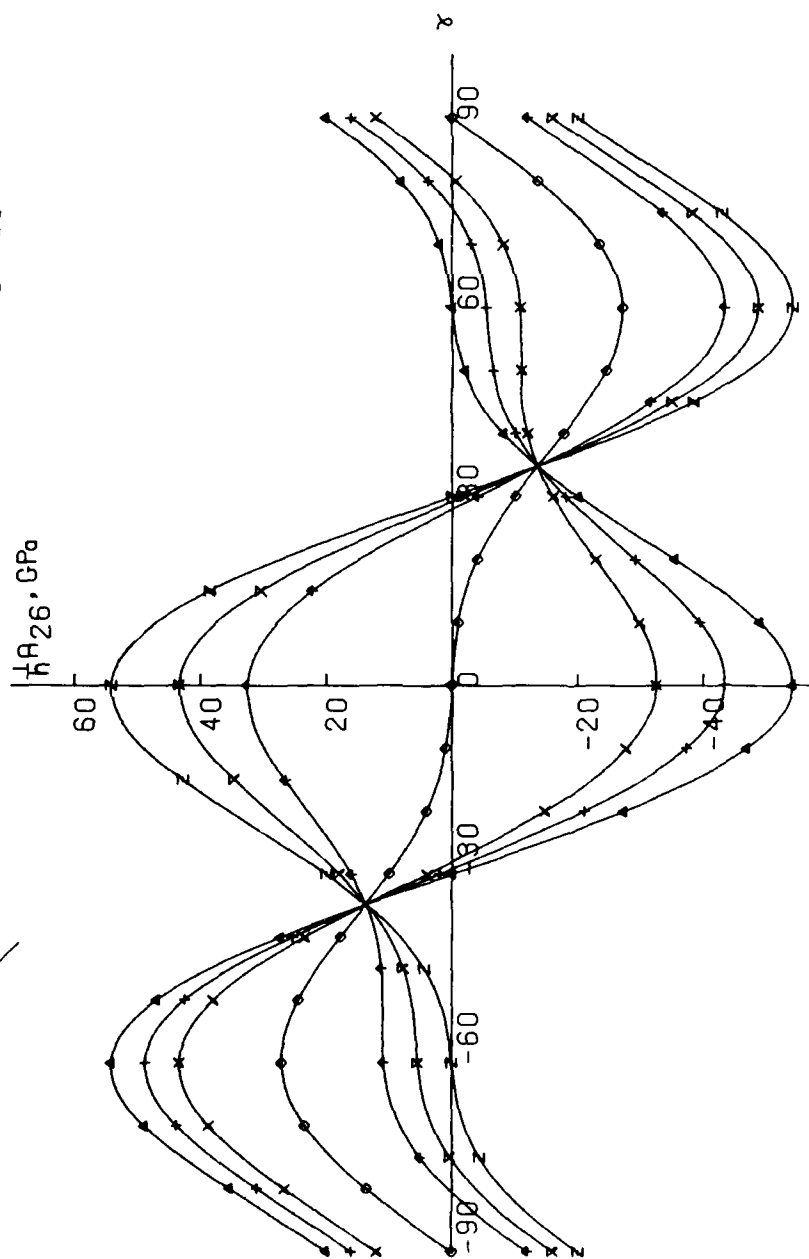
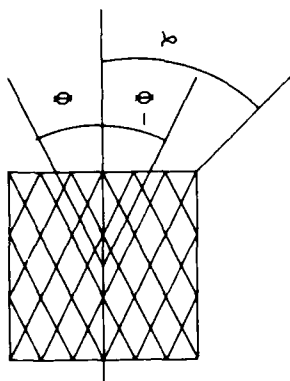


FIG.: 95



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)
 $\phi = 75$

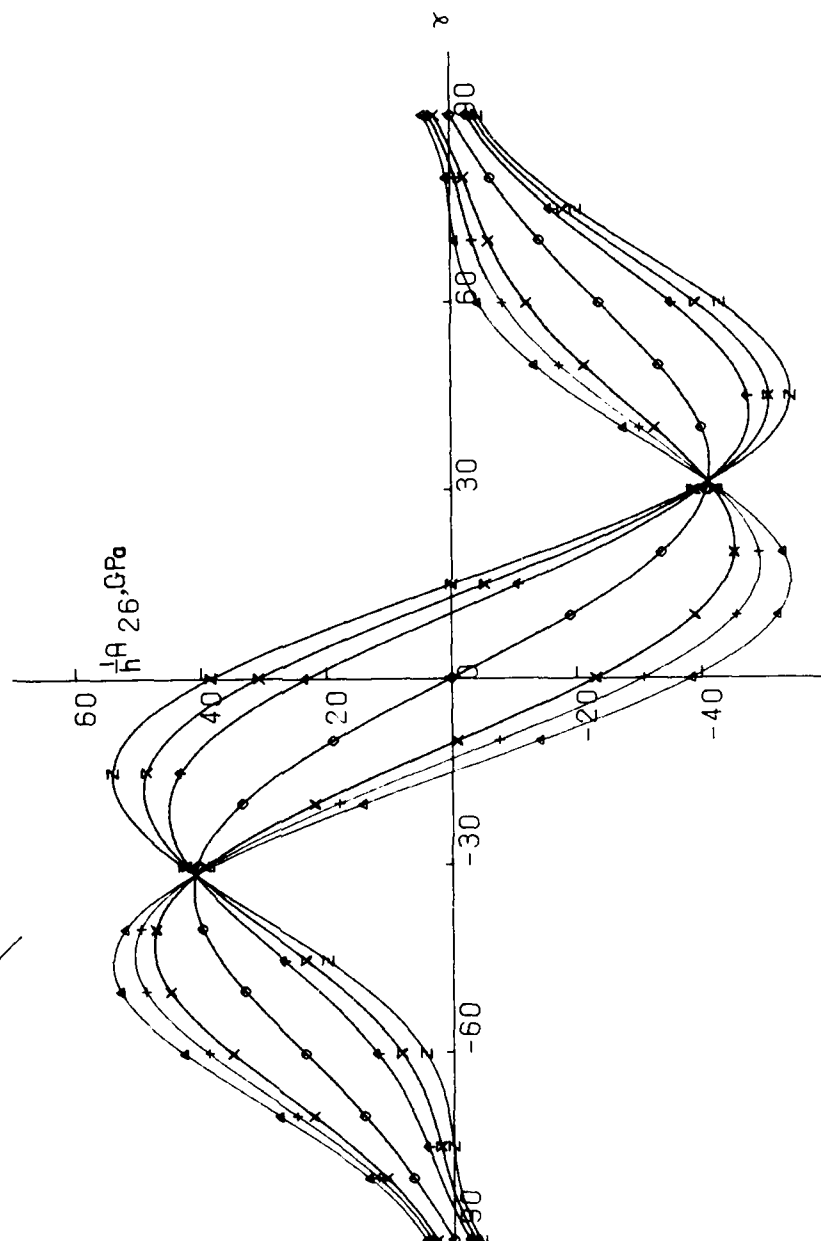
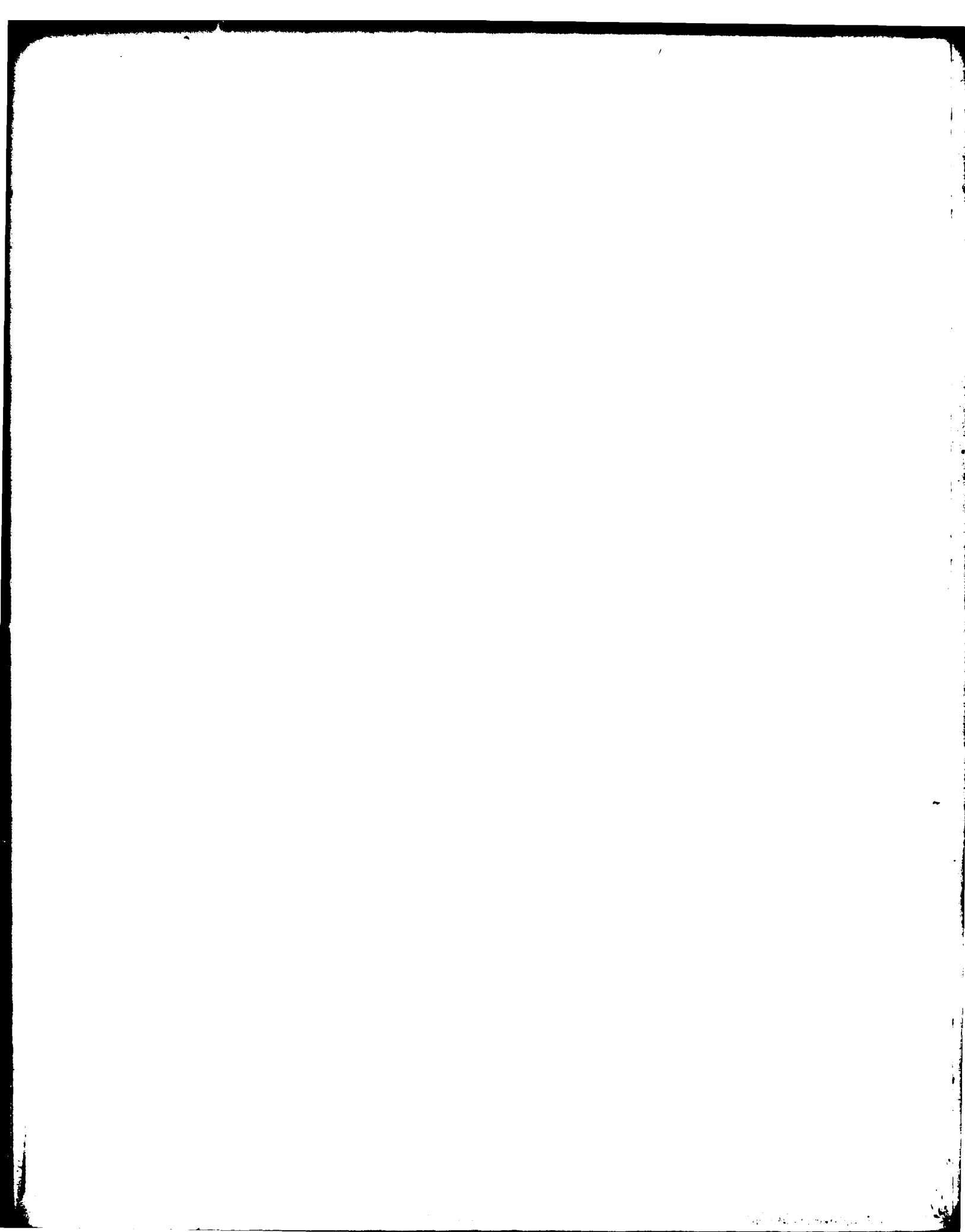
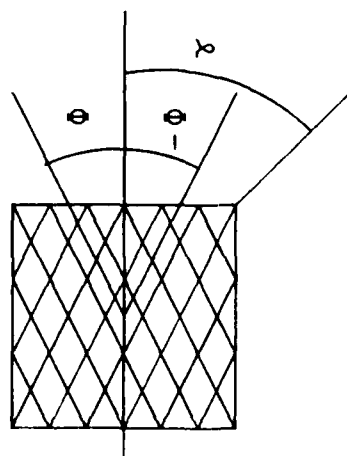


FIG.:96



COMPONENTS OF COMPLIANCE MATRIX FOR DIFFERENT BIDIRECTIONAL LAMINATES

COMPONENT	FIGURE NOS.
Q_{11}	97-112
Q_{22}	113-128
Q_{12}	129-144
Q_{66}	145-160
Q_{16}	161-176
Q_{26}	177-192



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\chi = -75$

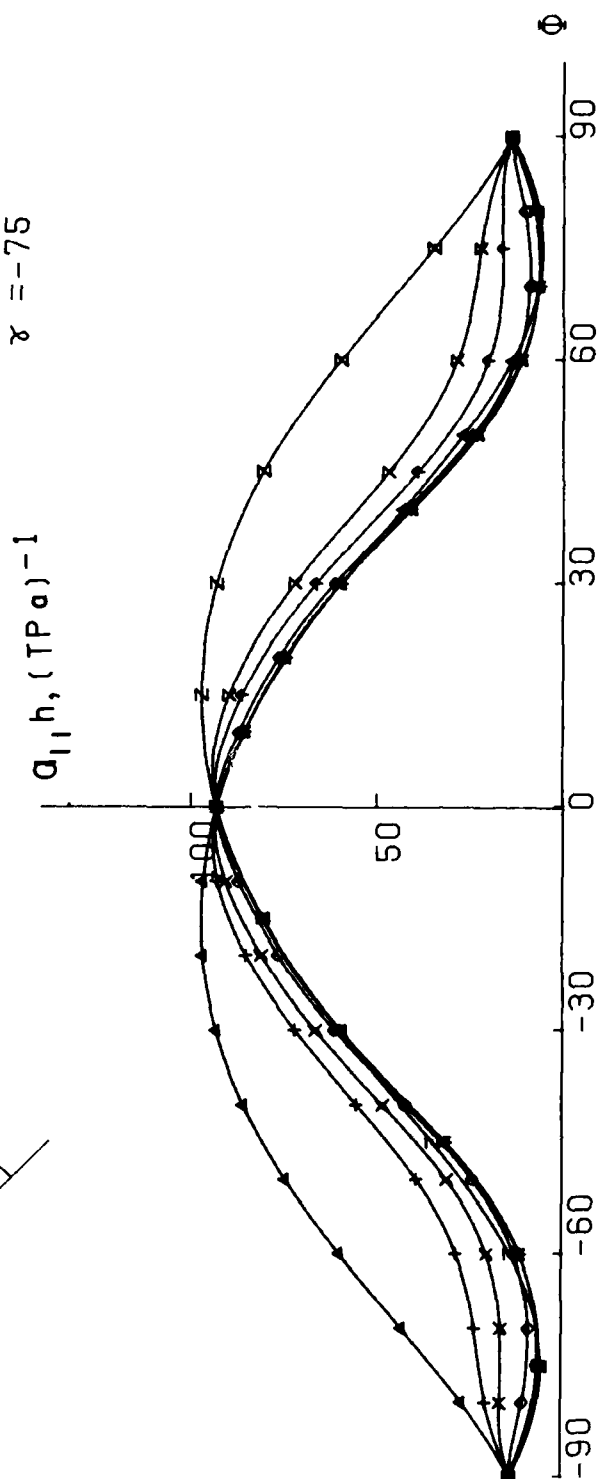
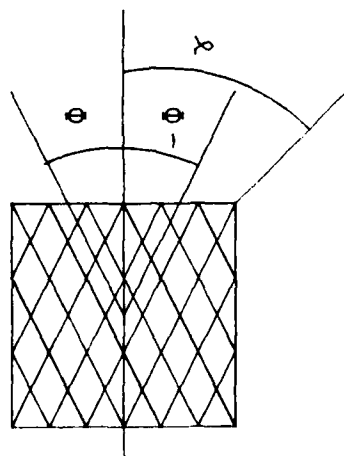


FIG.:97



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \square (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = -60$

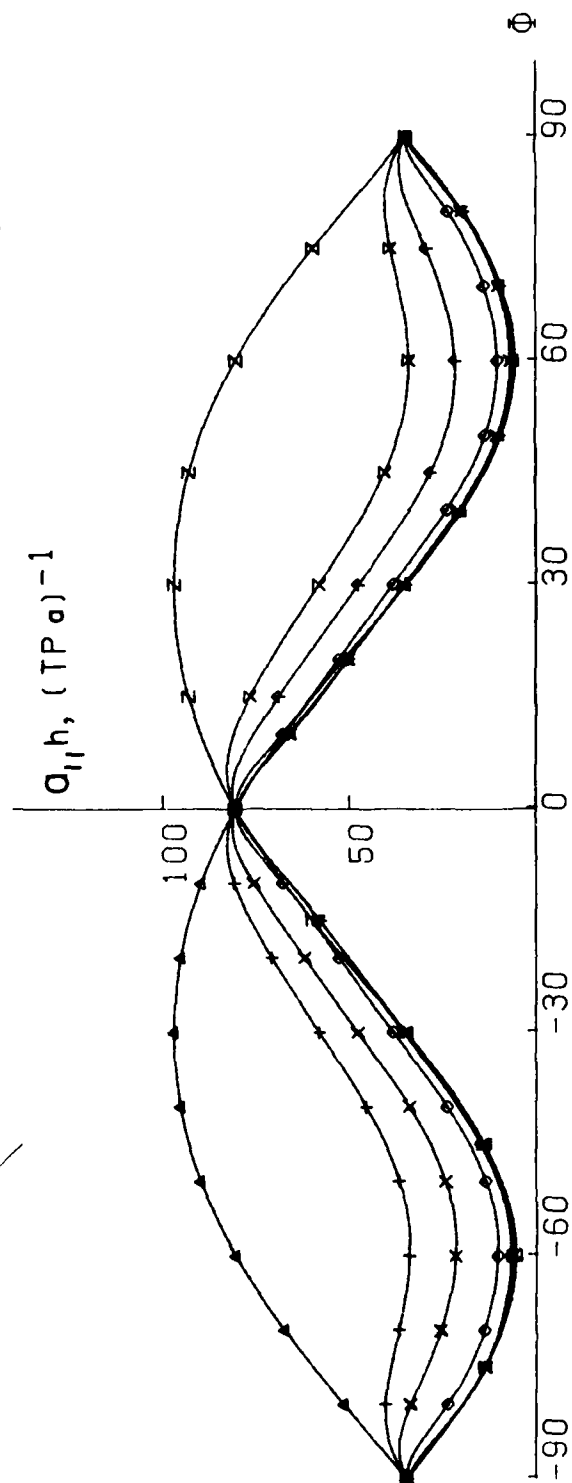
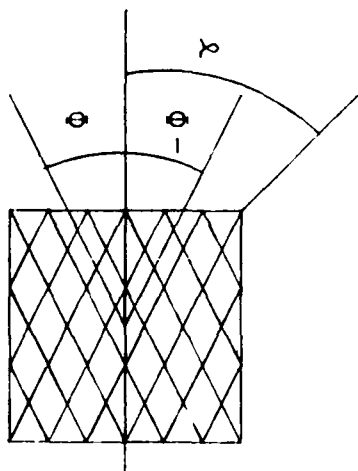


FIG.:98



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \square (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = -45$

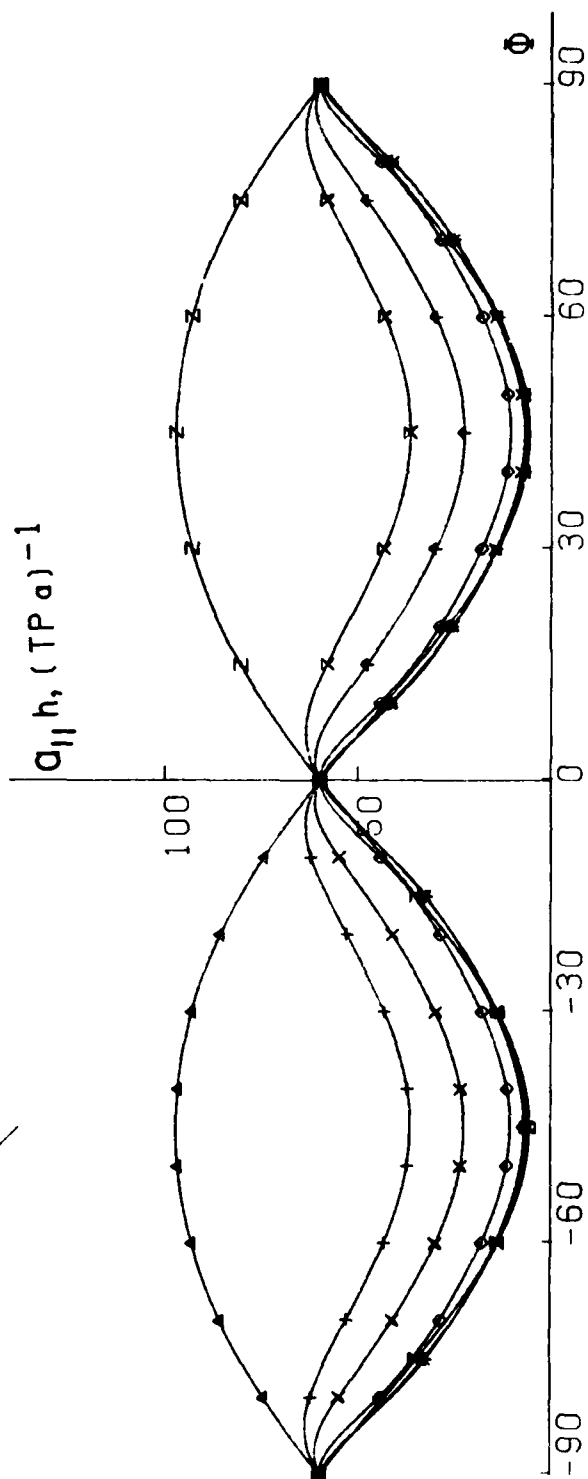
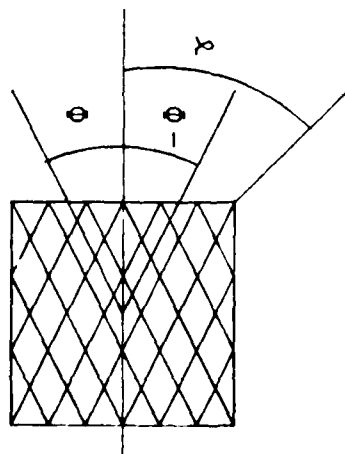


FIG.: 99



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \bowtie (1/9)
 Σ (0/1)

$\chi = -30$

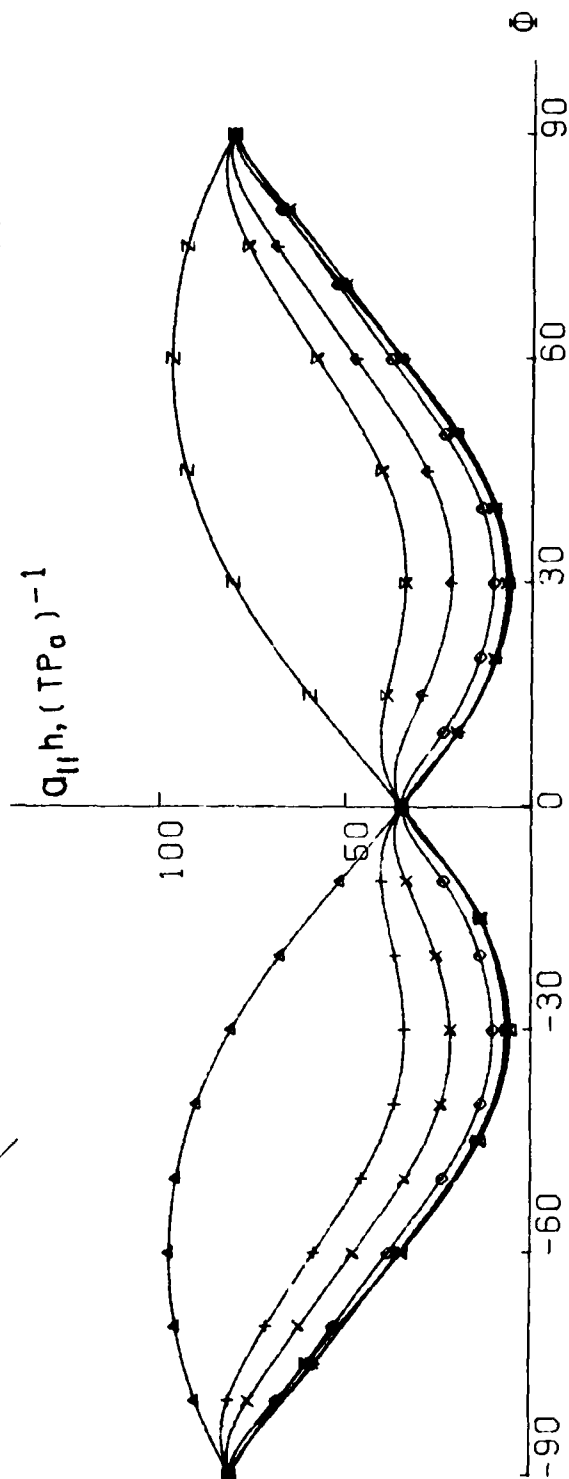
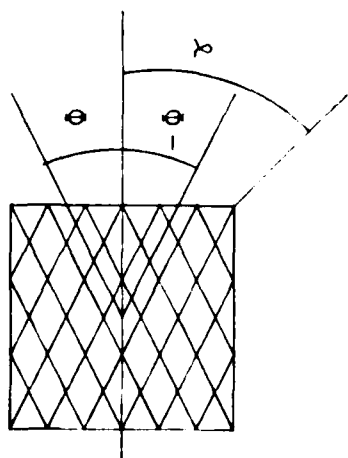


FIG.:100



	$\phi / -\phi$
Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
4	(1/4)
x	(1/9)
Z	(0/1)

$\chi = -15$

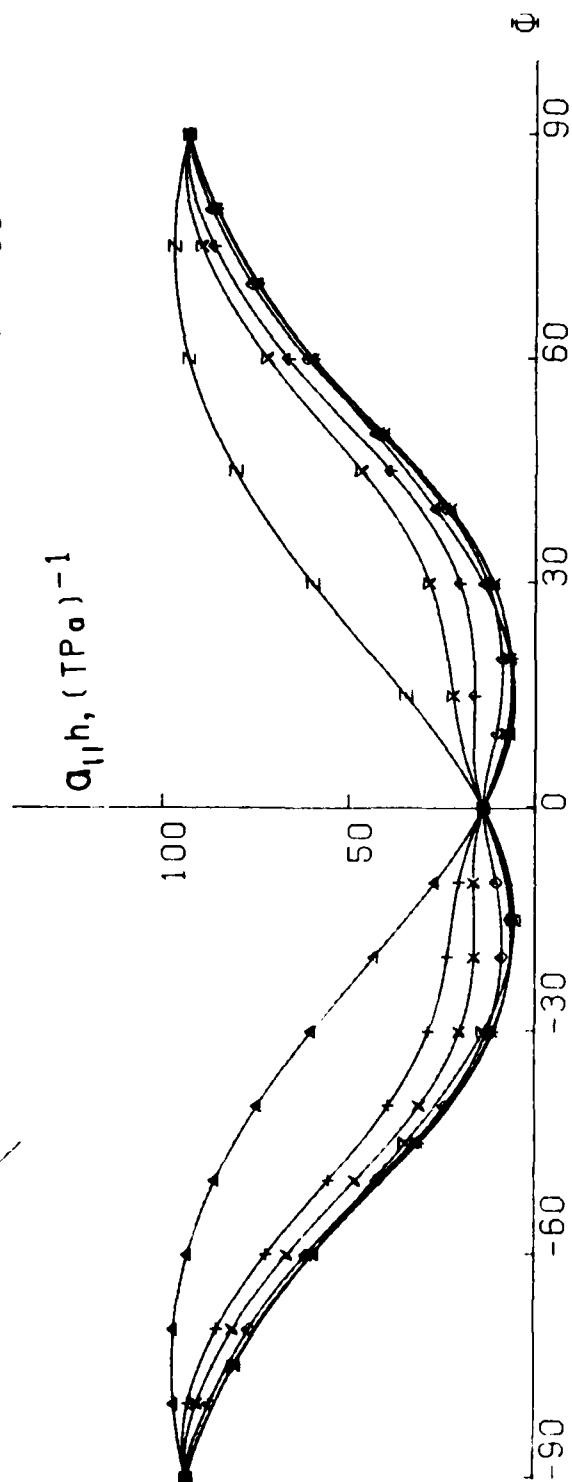
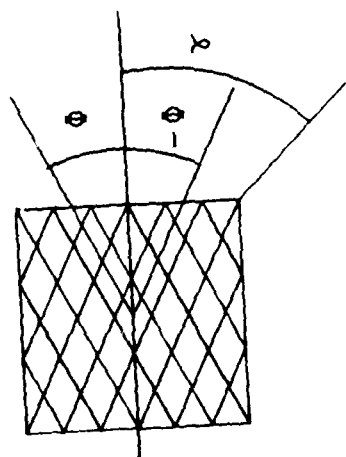


FIG.:101



$\phi / -\phi$

Δ	$(1/0)$
$+$	$(9/1)$
\times	$(4/1)$
\diamond	$(1/1)$
\oplus	$(1/4)$
\times	$(1/9)$
z	$(0/1)$

$\gamma=0$

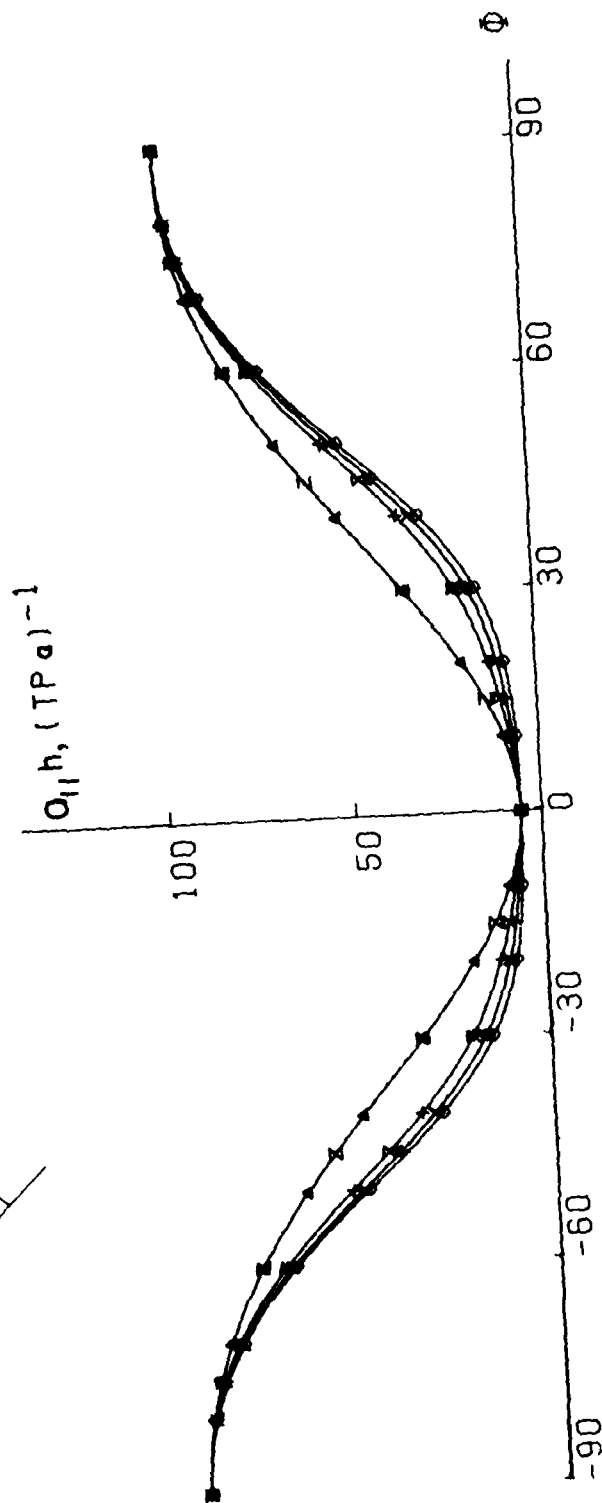
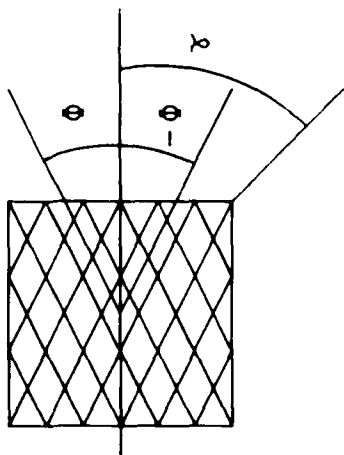


FIG.:102



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 \times (1/9)
 Z (0/1)

$\gamma = 15$

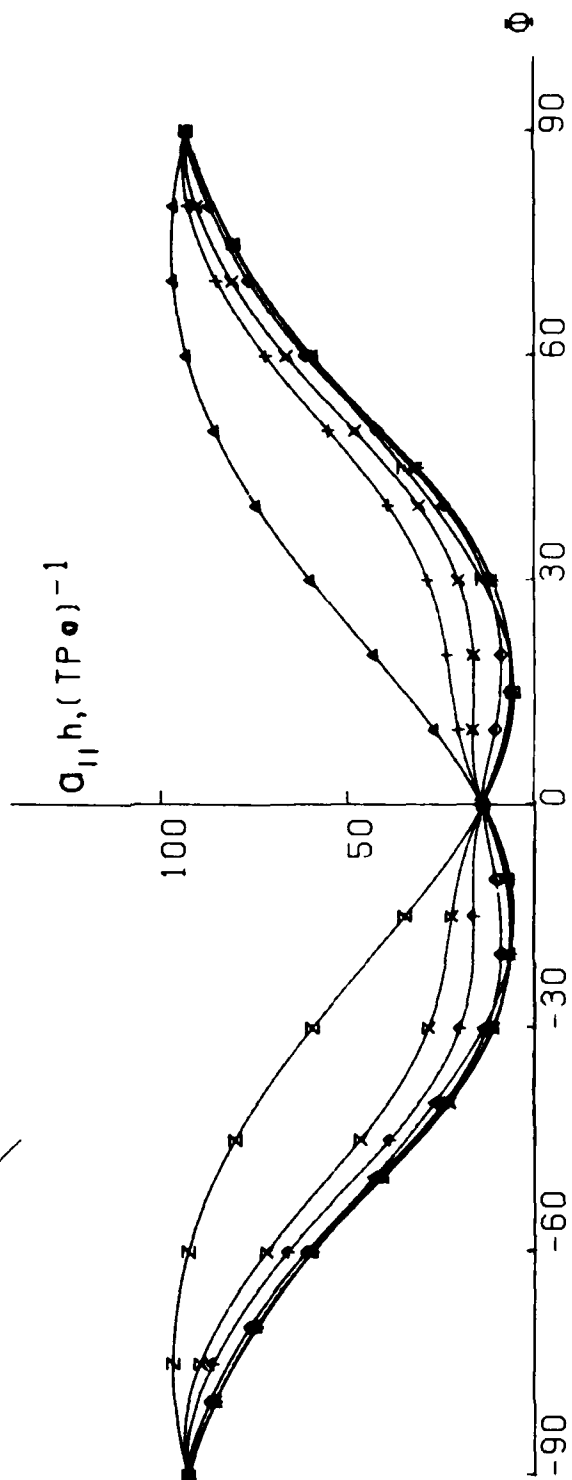
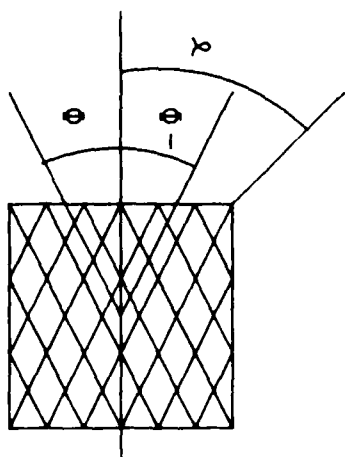


FIG.:103



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = 30$

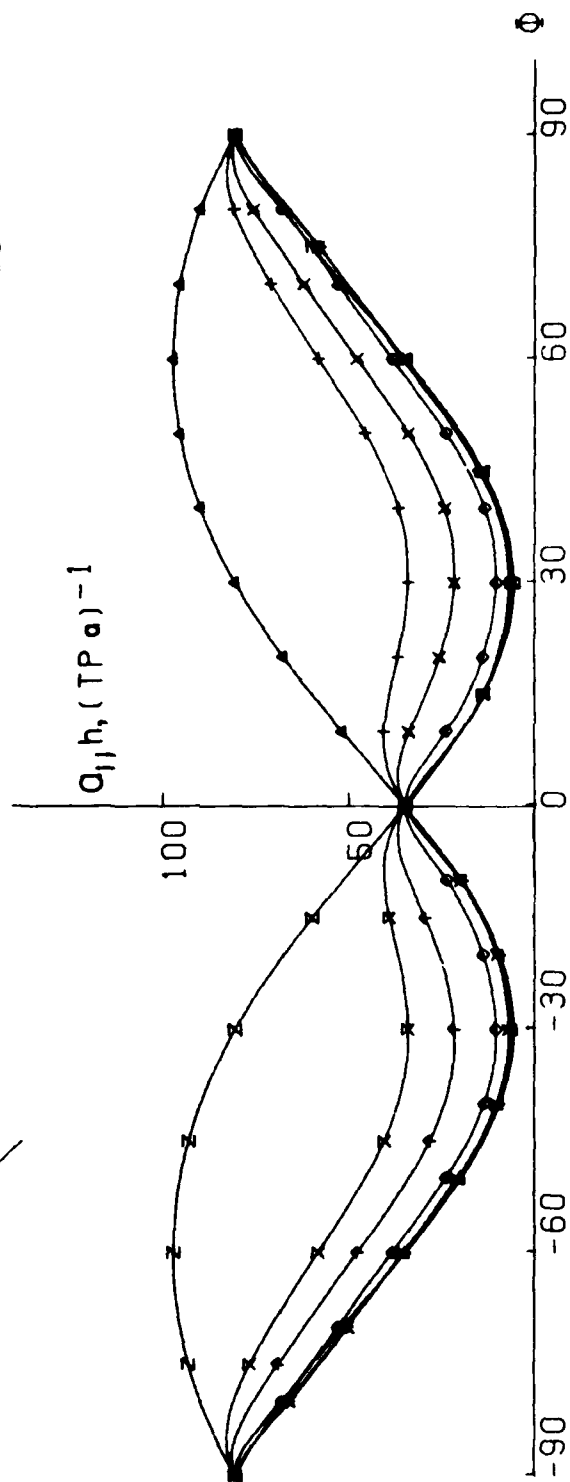
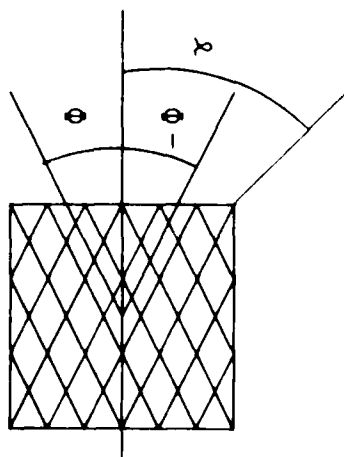


FIG.:104



	$\Phi / -\Phi$
Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
\oplus	(1/4)
\times	(1/9)
z	(0/1)

$\chi = 45$

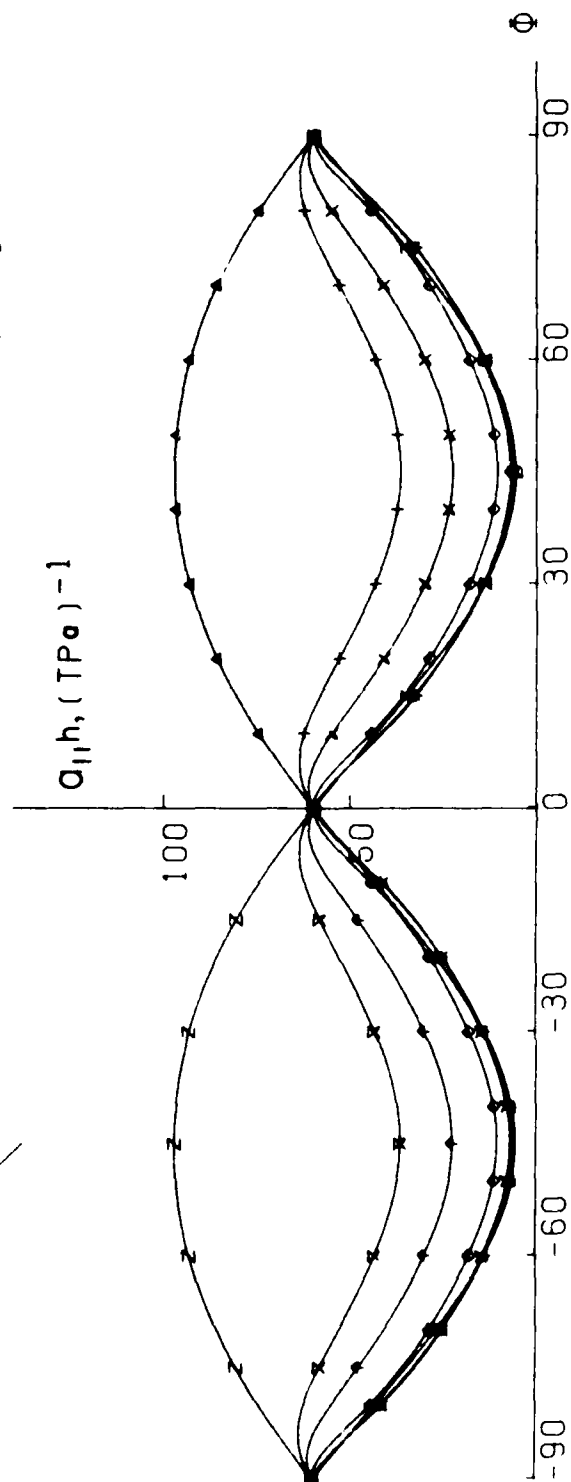
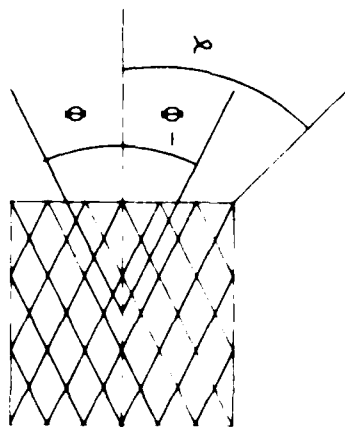


FIG.:105



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = 60$

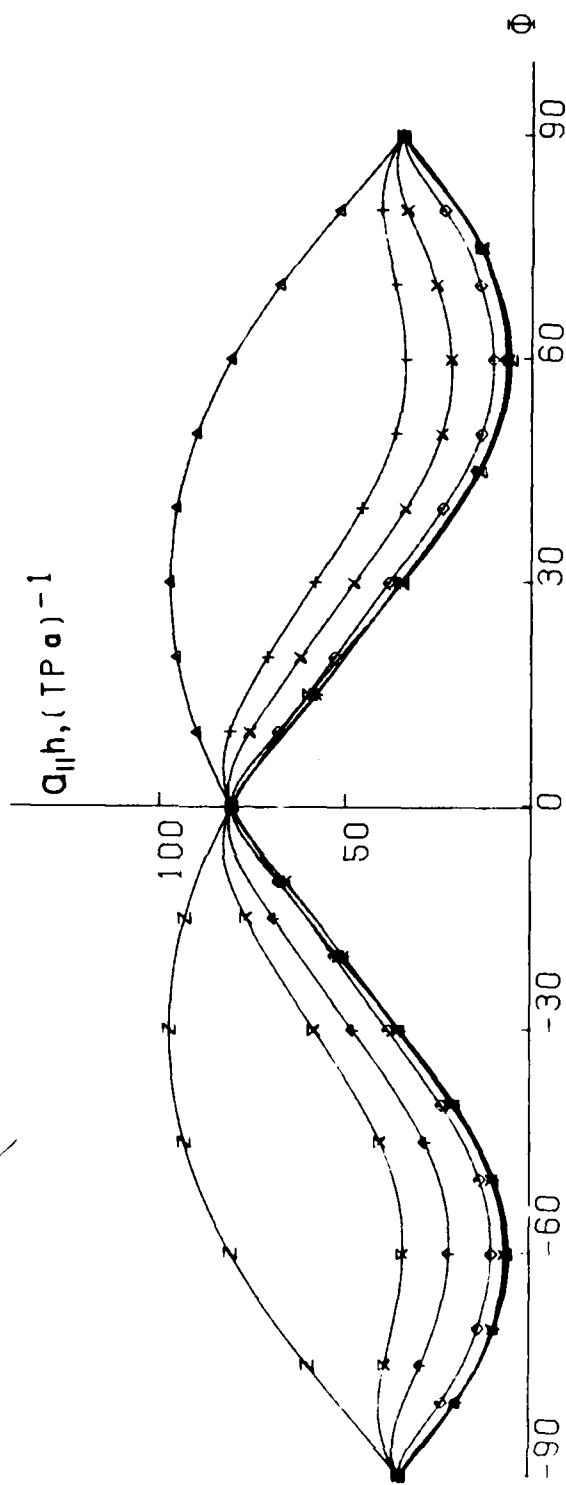
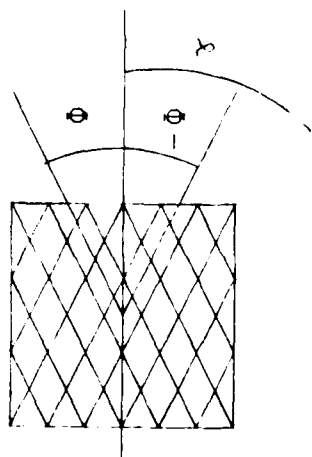


FIG.: 106



$\varphi / -\varphi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \bowtie (1/9)
 Σ (0/1)

$\gamma = 75^\circ$

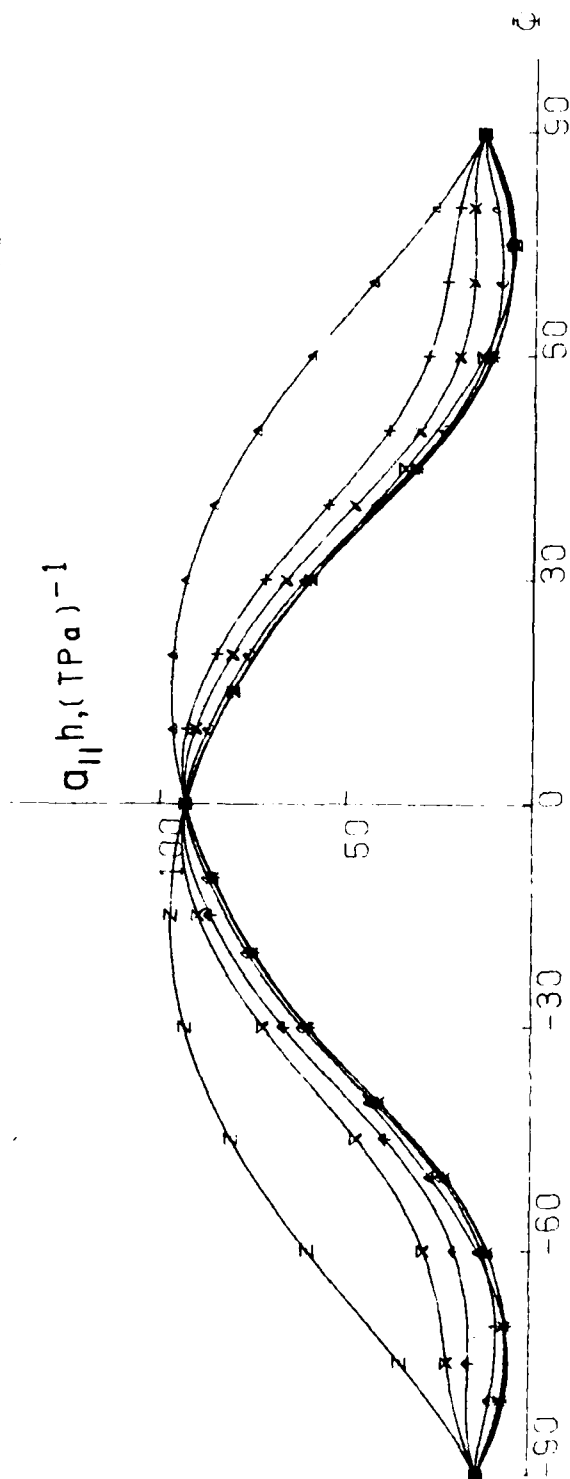
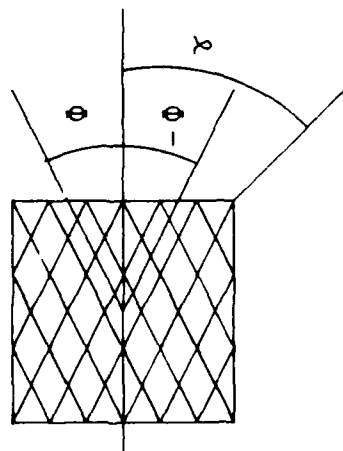


FIG.:107



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\phi = 15$

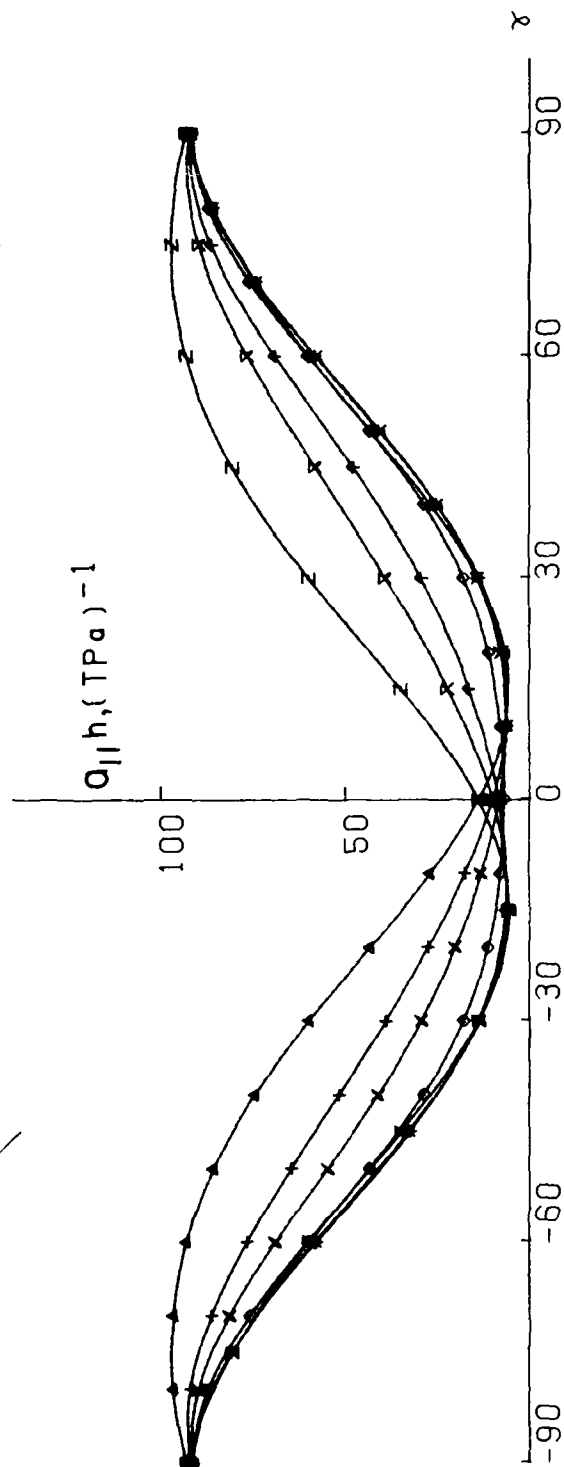
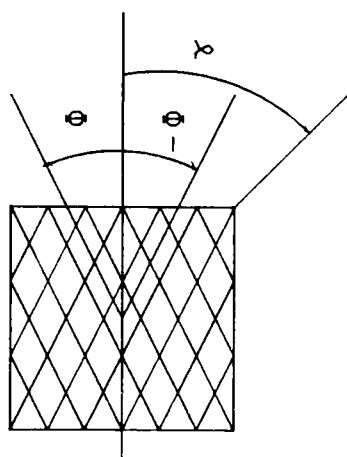


FIG.:108



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ϕ (1/4)
 \times (1/9)
 Σ (0/1)

$\Phi = 30$

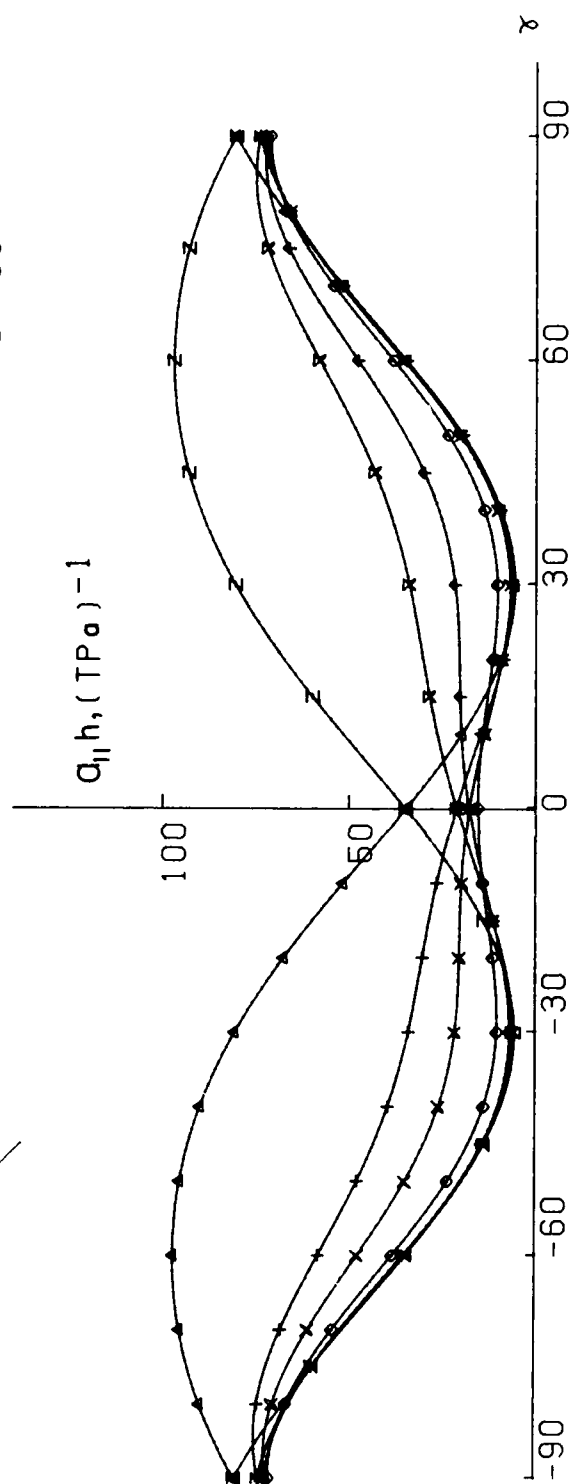


FIG.:109

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\Phi = 45$

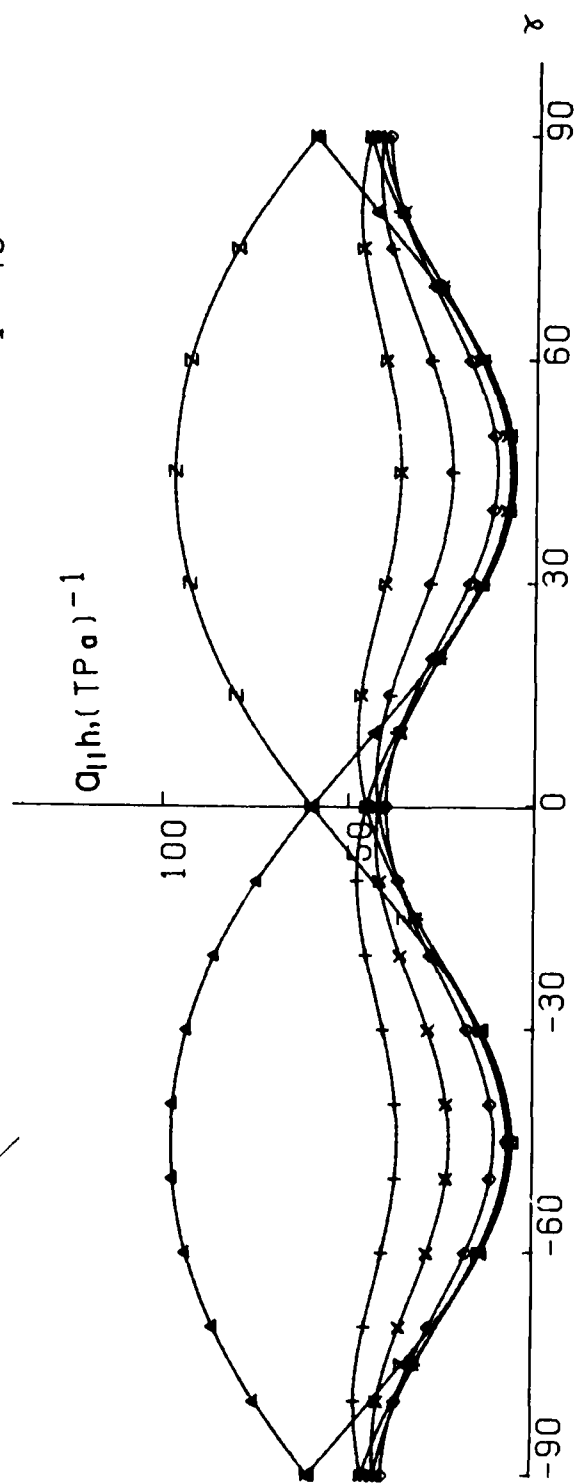
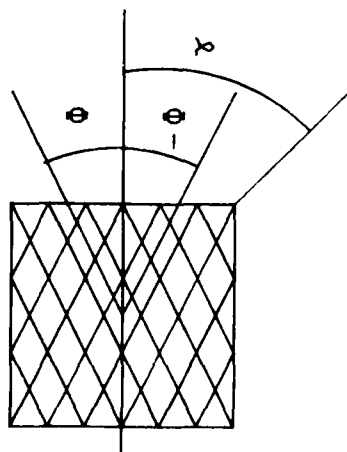
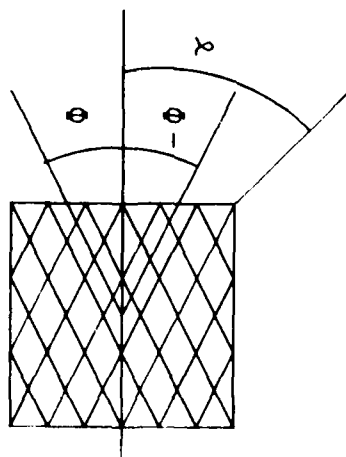


FIG.:110



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 \times (1/9)
 Σ (0/1)

$\Phi = 60$

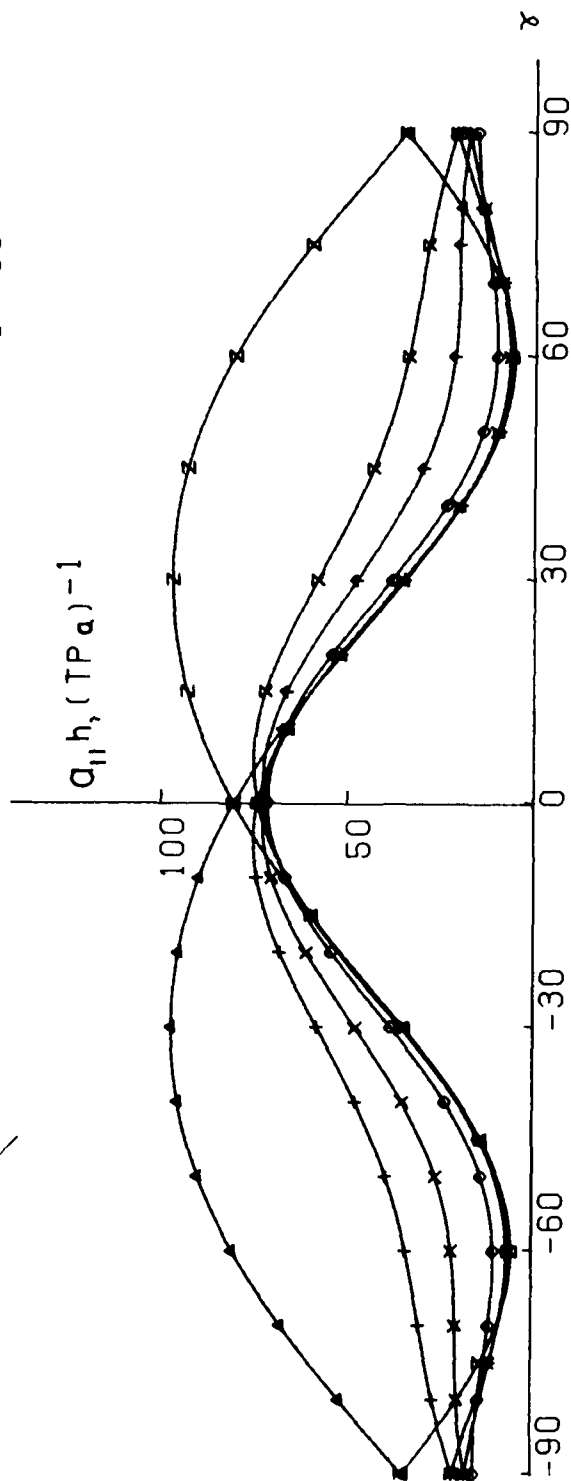
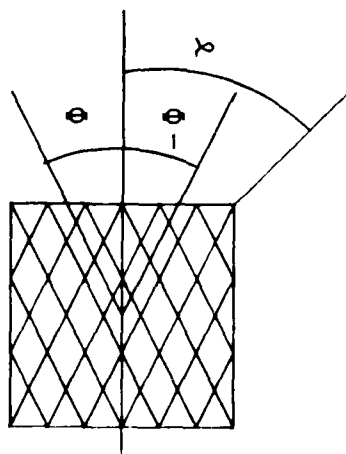


FIG.:111



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \bowtie (1/9)
 Σ (0/1)
 $\phi = 75$

141

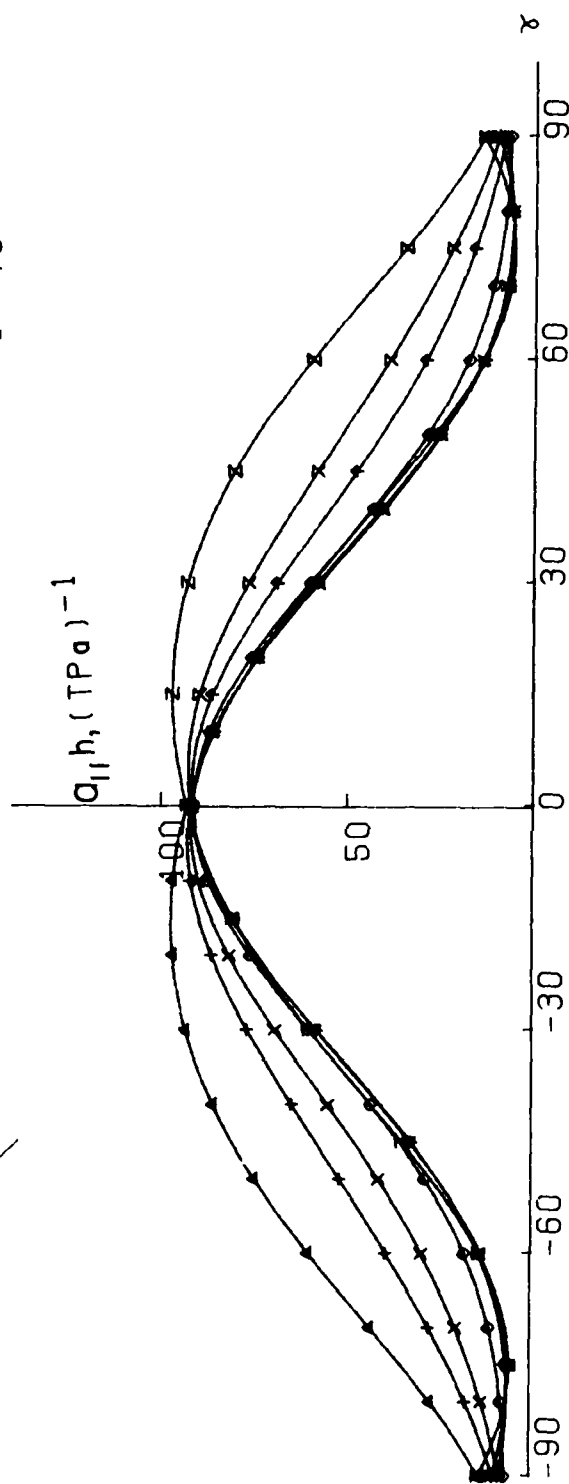


FIG.:112

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = -75$

$\sigma_{22} h, (TP \sigma)^{-1}$

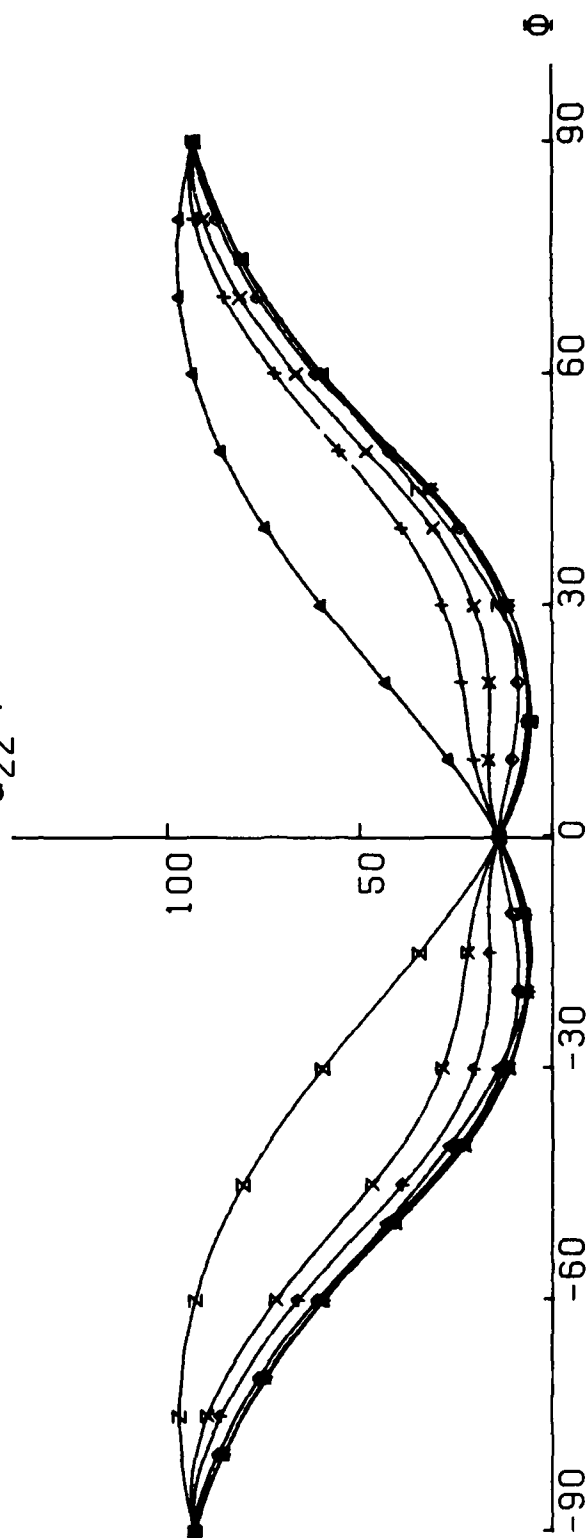
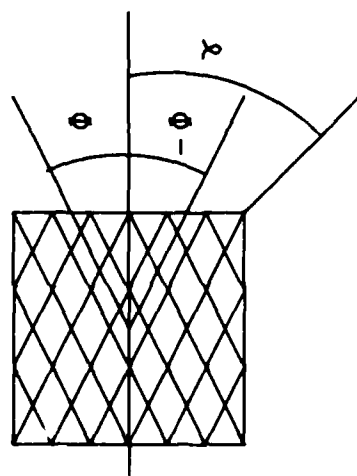
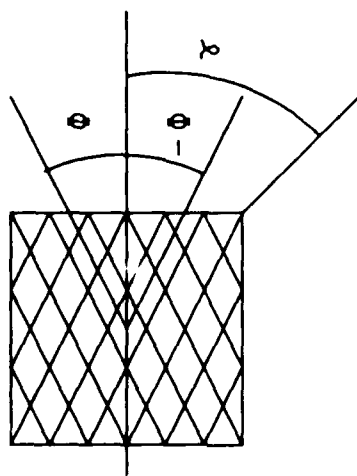


FIG.:113





$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\alpha_{22} h, (TP\alpha)^{-1}$ $\chi = -60$

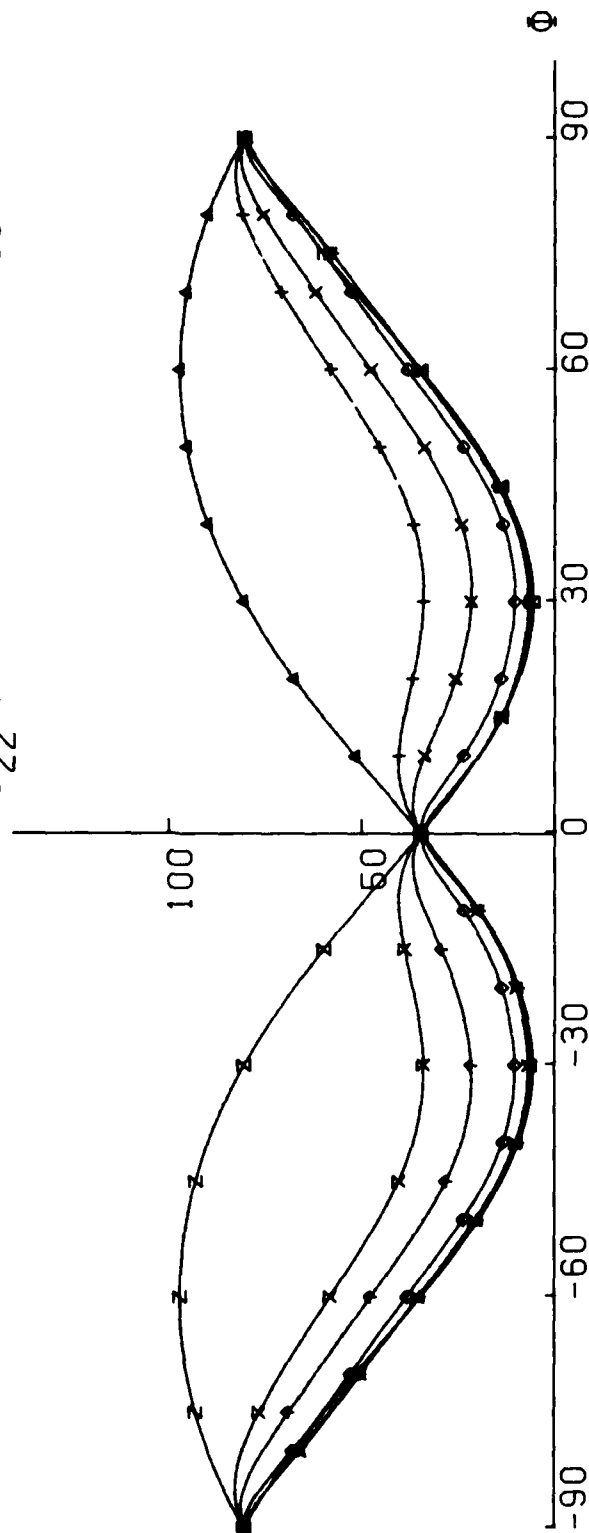
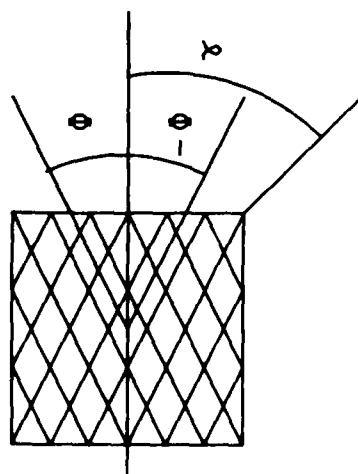


FIG.:114



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\chi = -45$

$\sigma_{22} h, (\text{TPa})^{-1}$

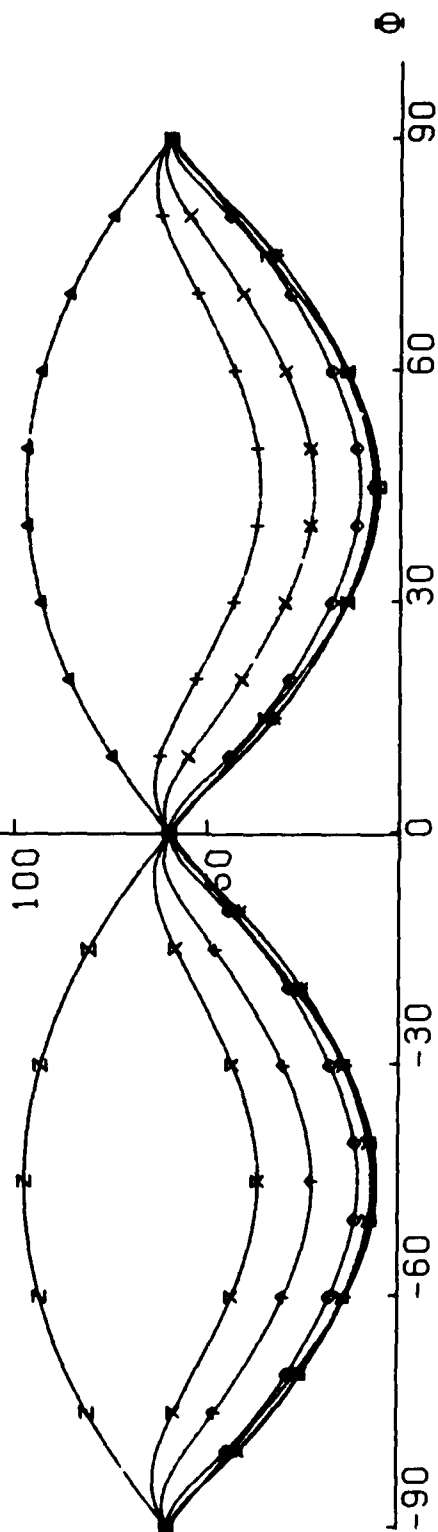
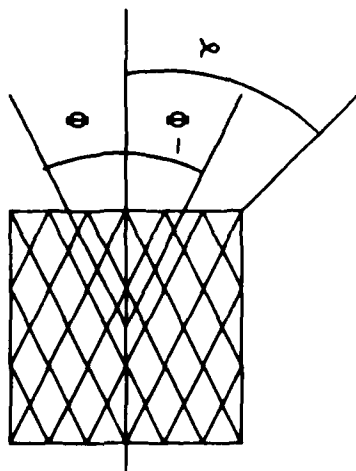


FIG.:115



ϕ/ϕ	
Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
∇	(1/4)
\times	(1/9)
Z	(0/1)

$\sigma_{22} h, (TP\sigma)^{-1}$ $\chi = -30$

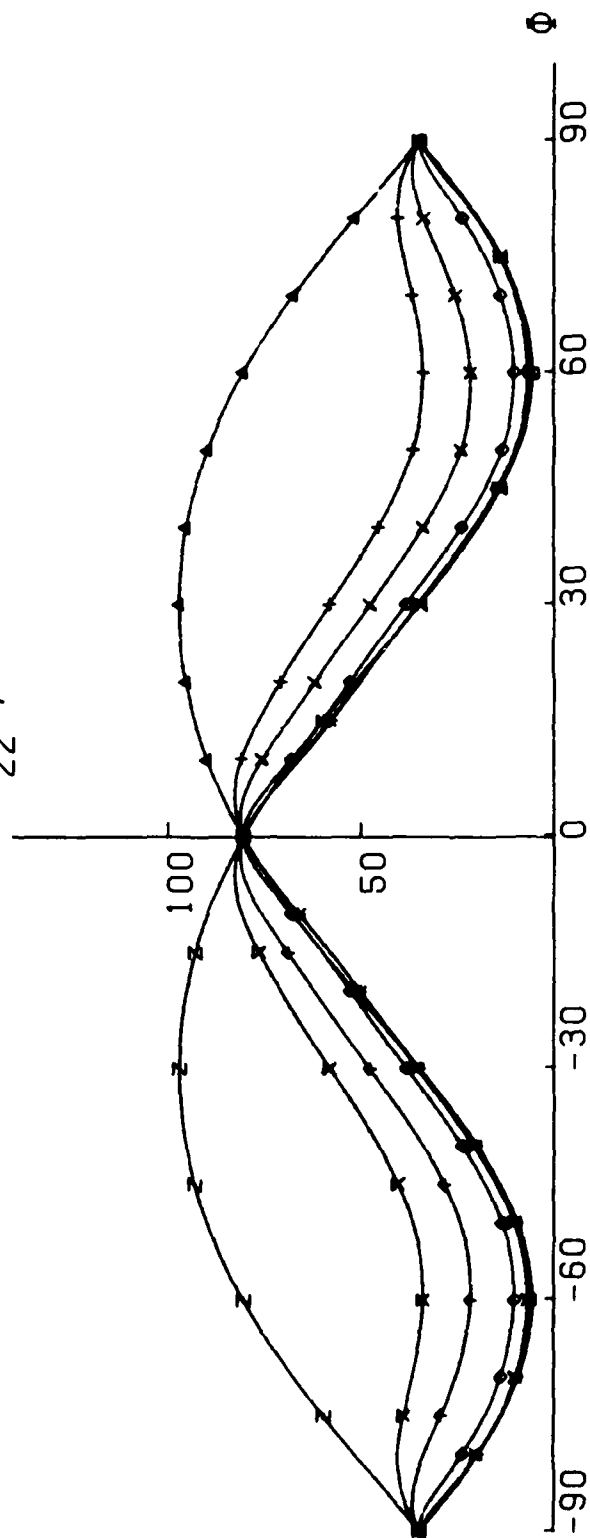
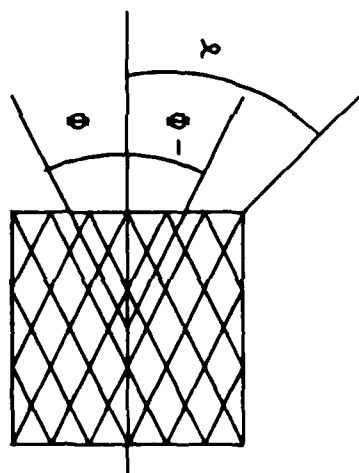


FIG.:116

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = -15$



$a_{22} h_1 (TP a)^{-1}$

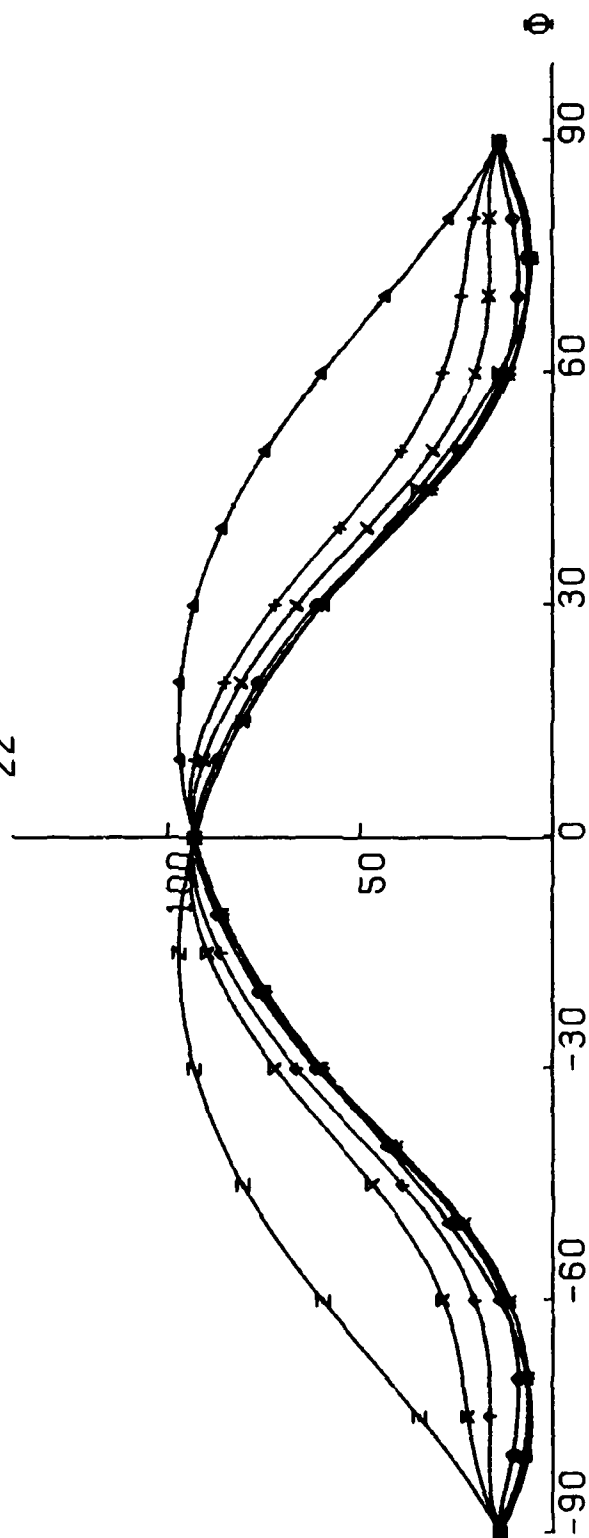
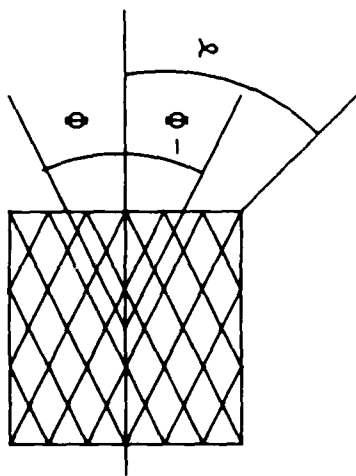


FIG.:117



$\Phi / -\Phi$	
Δ	(1/0)
+	(9/1)
X	(4/1)
\diamond	(1/1)
∇	(1/4)
\times	(1/9)
Z	(0/1)

$\chi = 0$

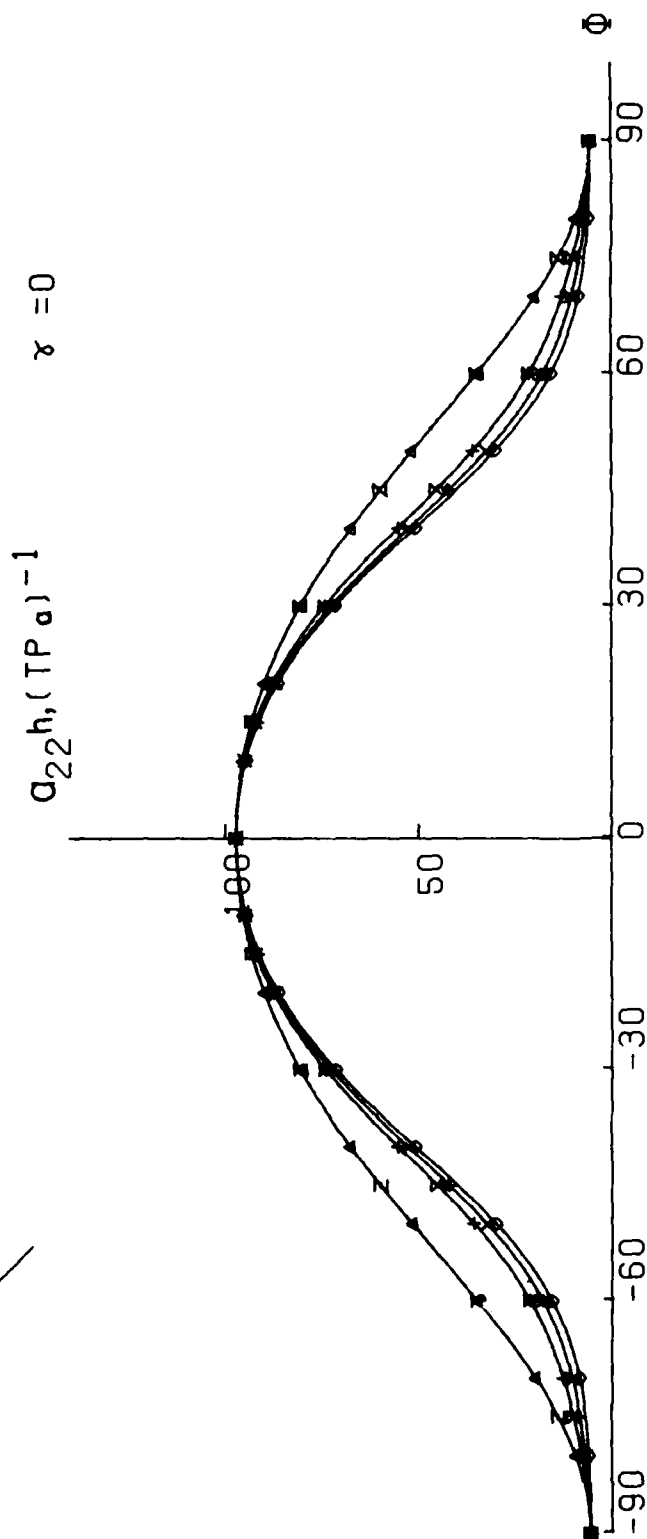
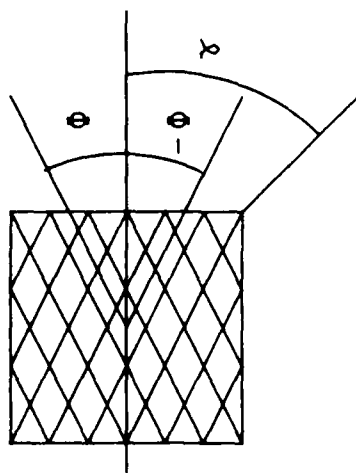


FIG.:118



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = 15$

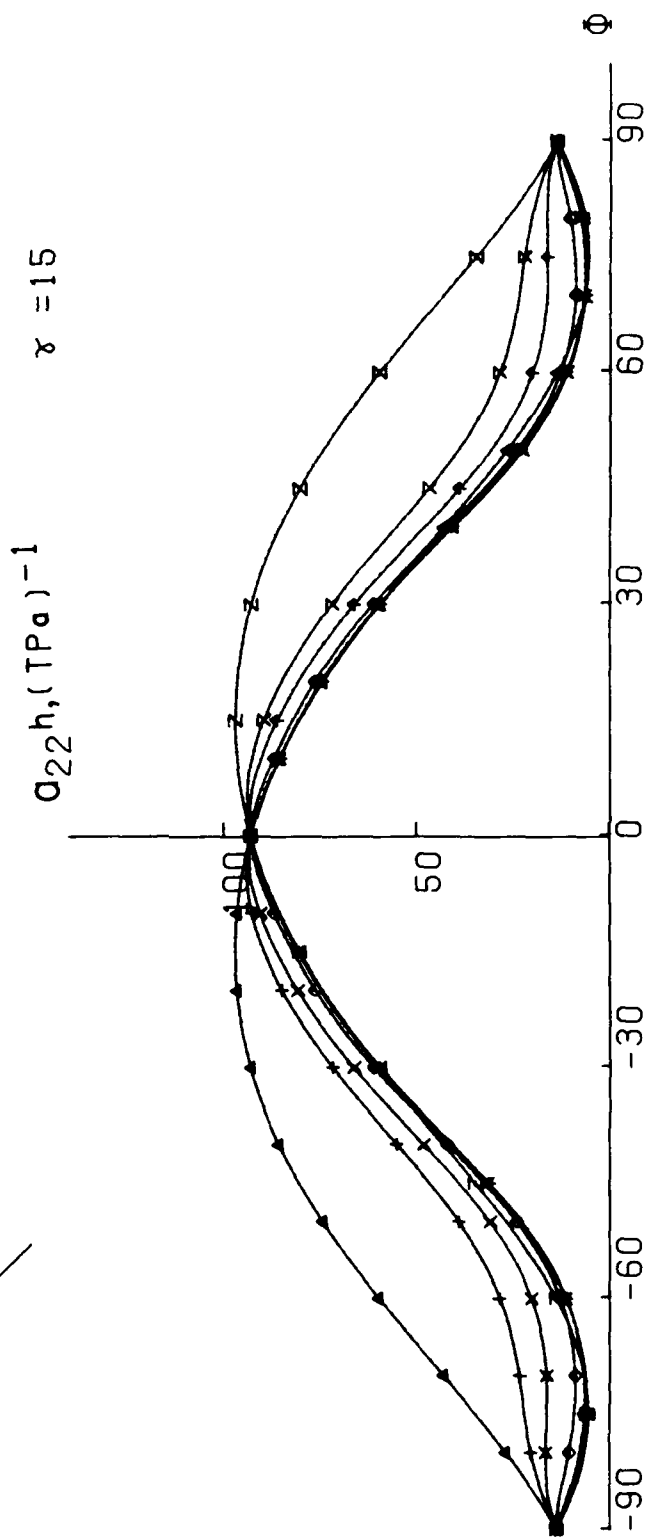
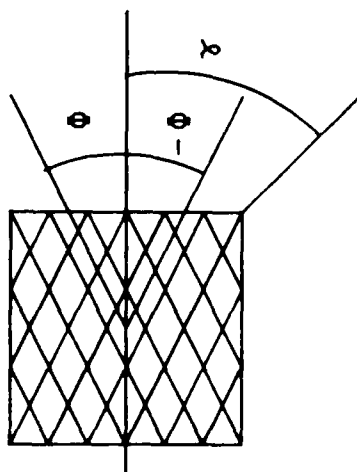


FIG.:119



Φ/Φ	
Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
\clubsuit	(1/4)
\times	(1/9)
Z	(0/1)

$\gamma = 30$

$Q_{22}h, (TP\sigma)^{-1}$

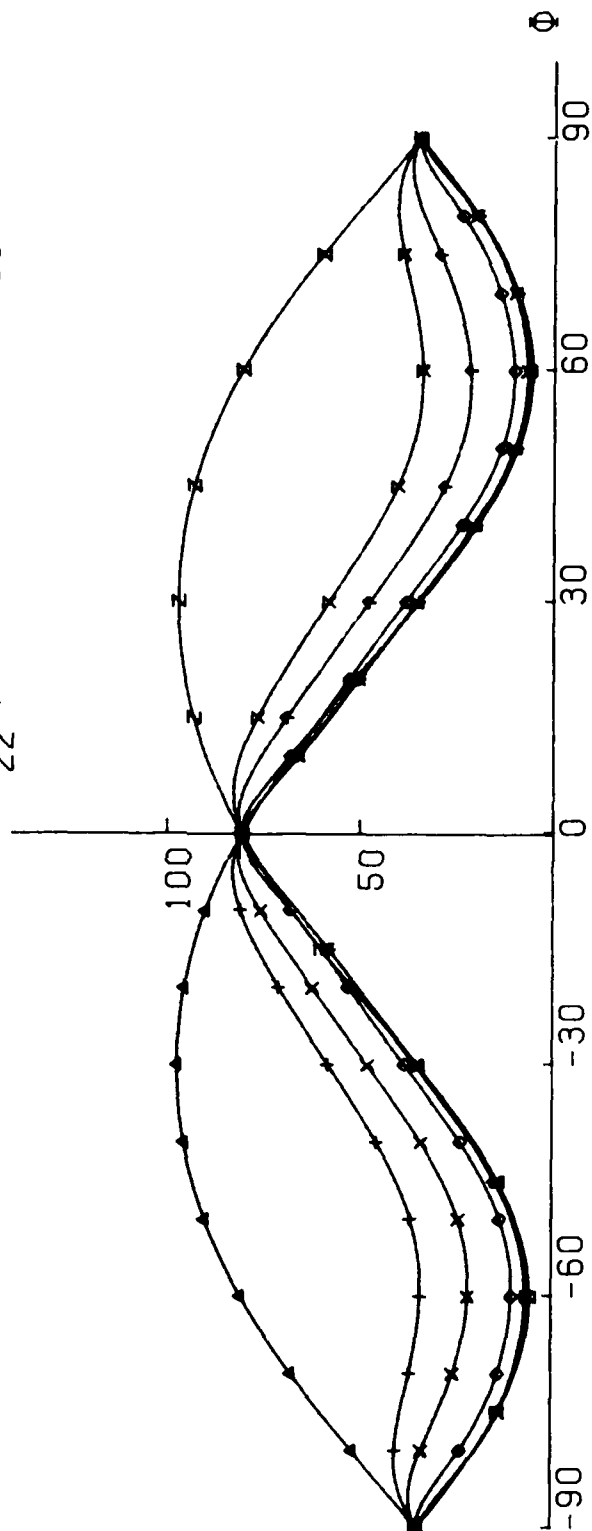
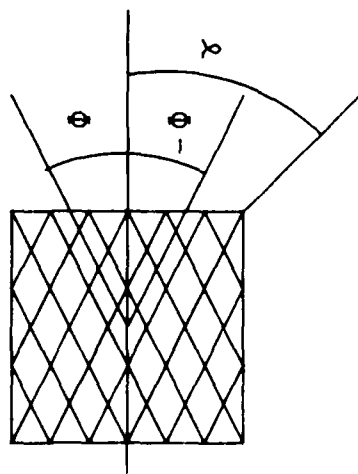


FIG.:120



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\sigma_{22} h_1 (TP \sigma)^{-1}$
 $\gamma = 45$

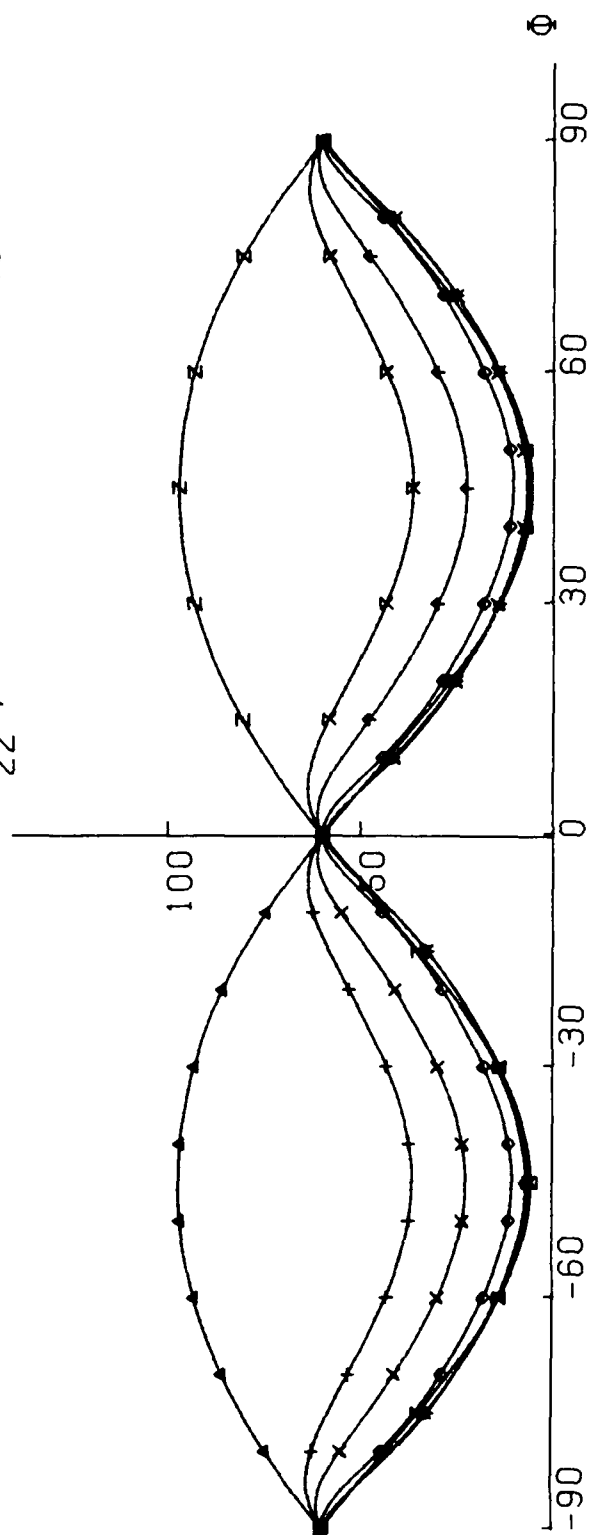
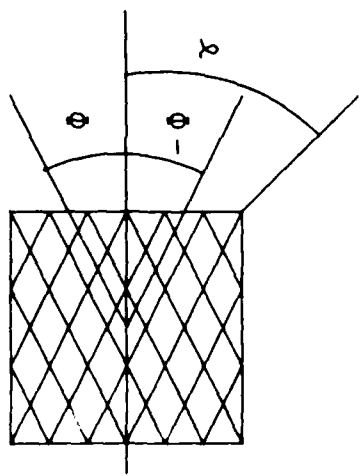


FIG.:121



- $\Phi / -\Phi$
- Δ (1/0)
 - $+$ (9/1)
 - \times (4/1)
 - \diamond (1/1)
 - ∇ (1/4)
 - \times (1/9)
 - Σ (0/1)

$\chi = 60$

$\sigma_{22} h, (\text{TPa})^{-1}$

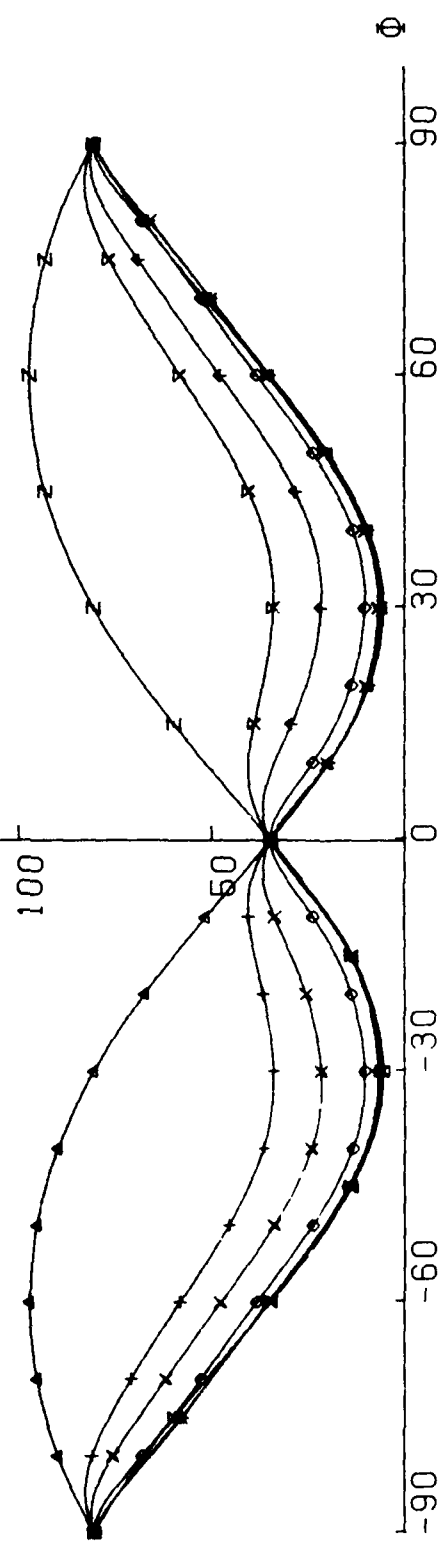
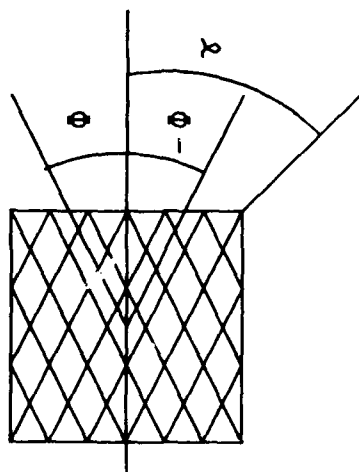


FIG.:122



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4,1)
 \diamond (1/1)
 Φ (1/4)
 \times (1/9)
 Σ (0/1)

$\alpha = 75$

$\sigma_{22} h, (TP\sigma)^{-1}$

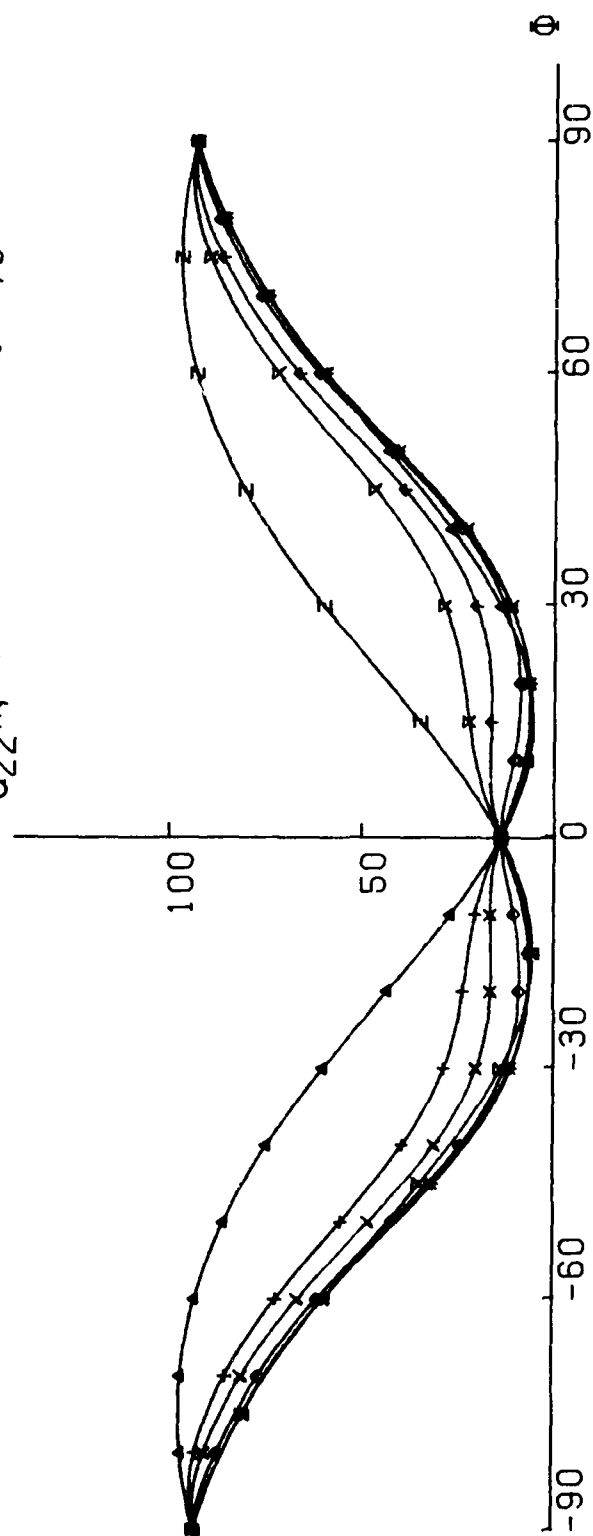
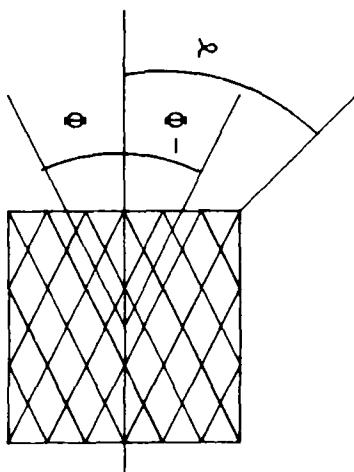


FIG.:123



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\phi = 15$

$\alpha_{22} h, (TP\phi)^{-1}$

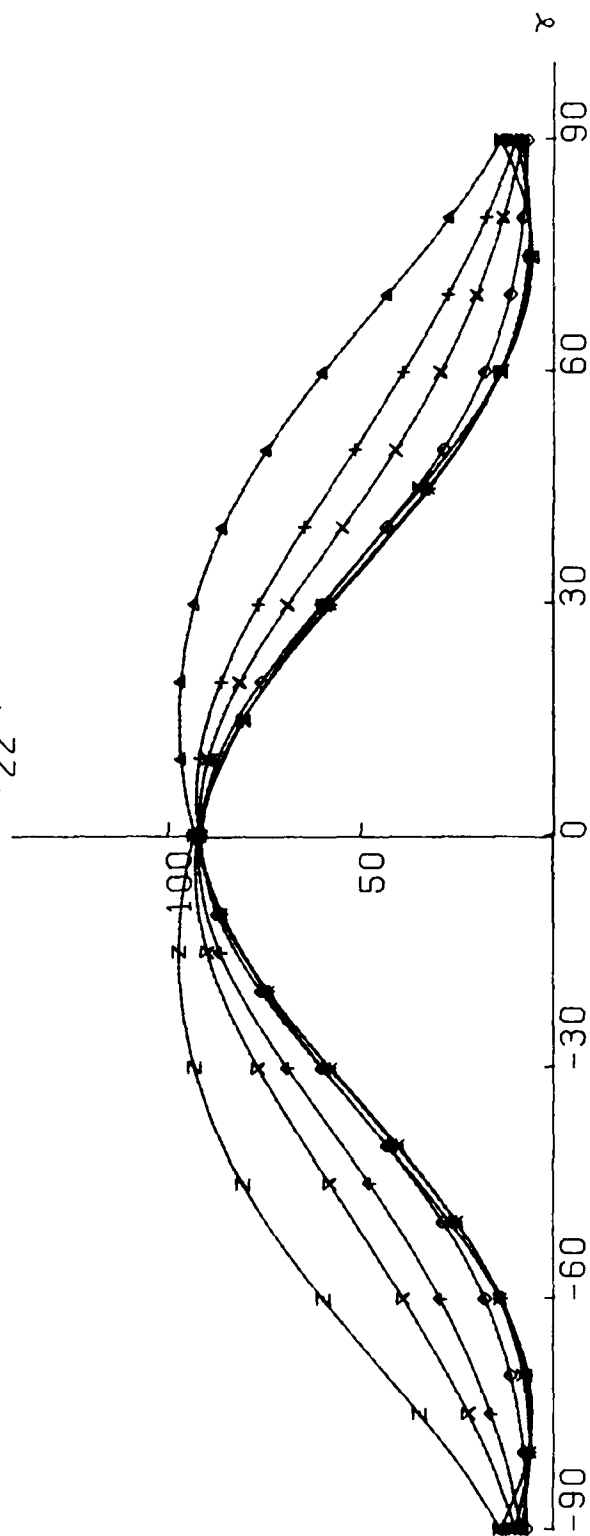
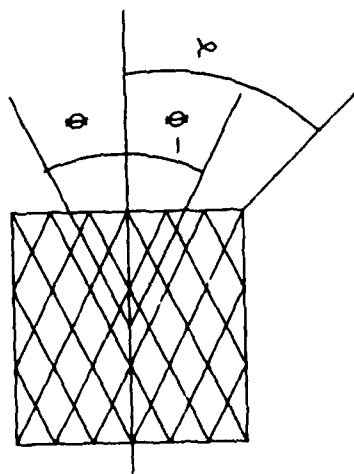


FIG.:124



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 z (0/1)

$\phi = 30$

$Q_{22}h, (TP\sigma)^{-1}$

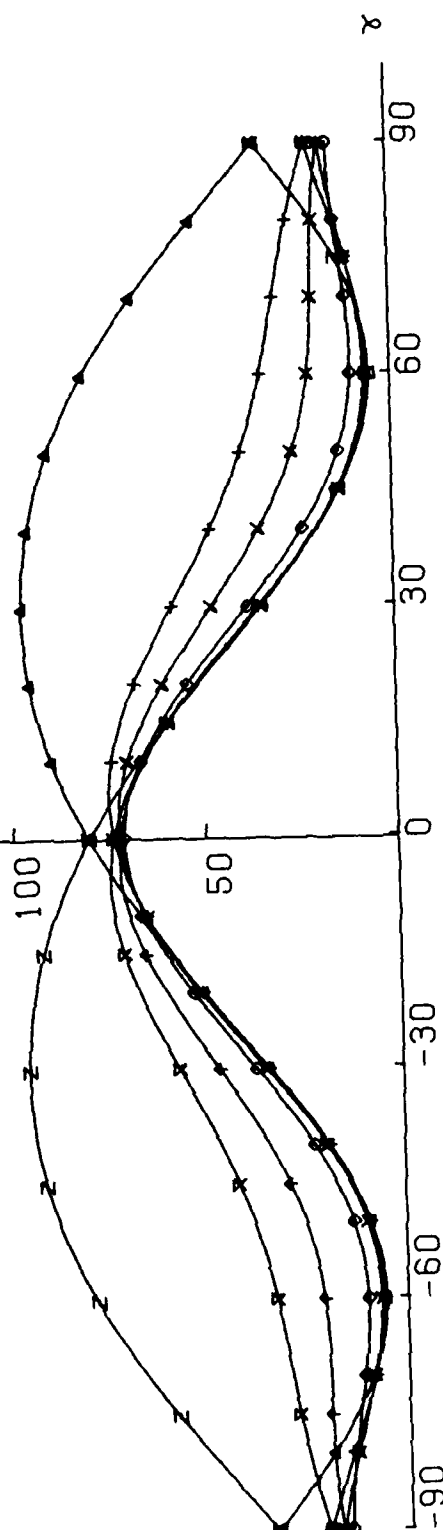
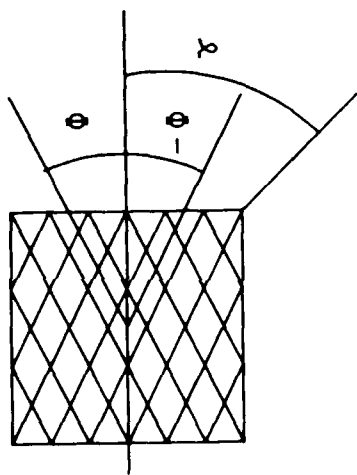


FIG.:125



$-\Phi/\Phi$

Δ (1/0)

$+$ (9/1)

\times (4/1)

\diamond (1/1)

\oplus (1/4)

\otimes (1/9)

Σ (0/1)

$\Phi = 45$

$\sigma_{22} h_1 (\Gamma P a)^{-1}$

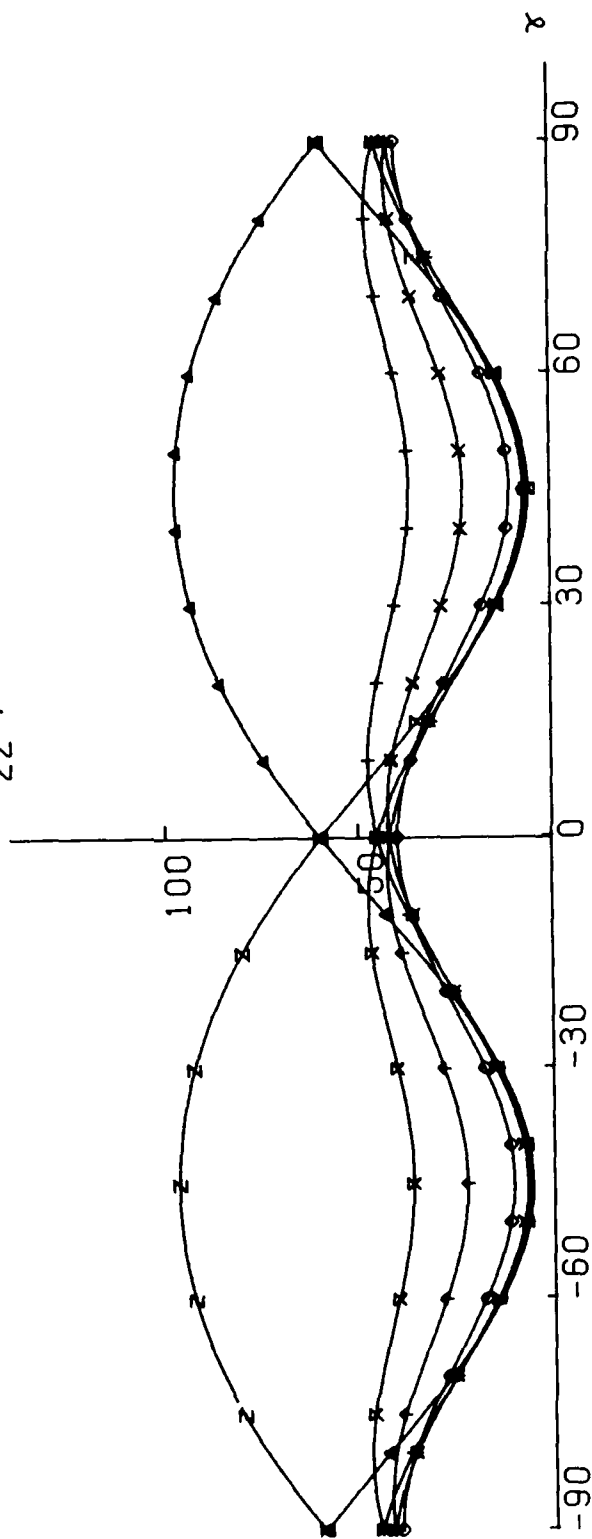
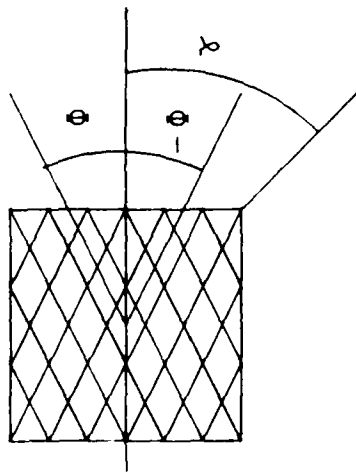


FIG.:126



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$a_{22}h, (TPa)^{-1}$ $\phi = 60$

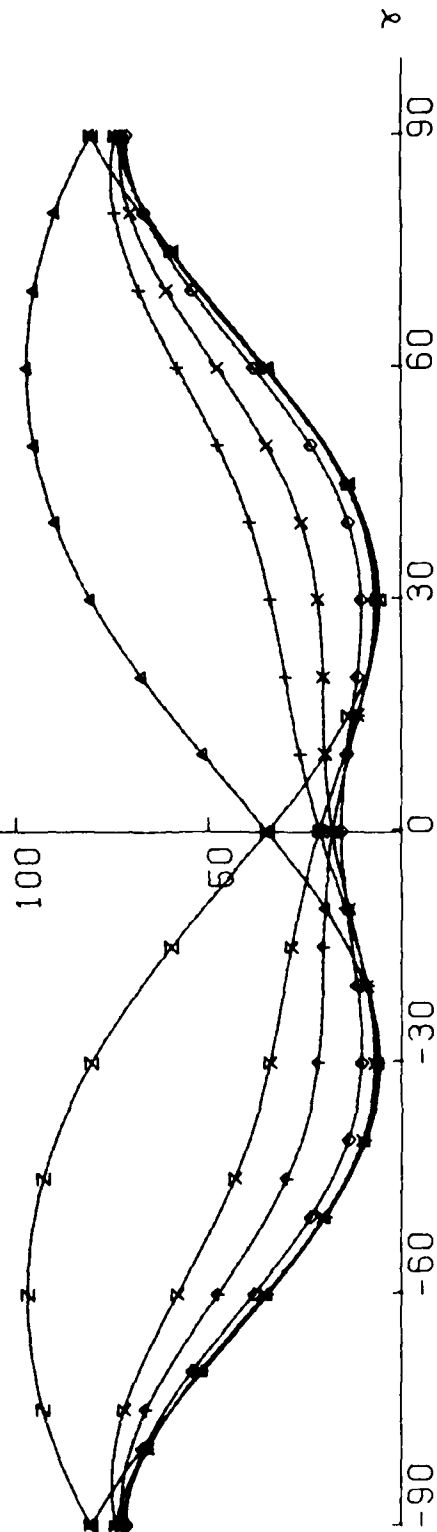
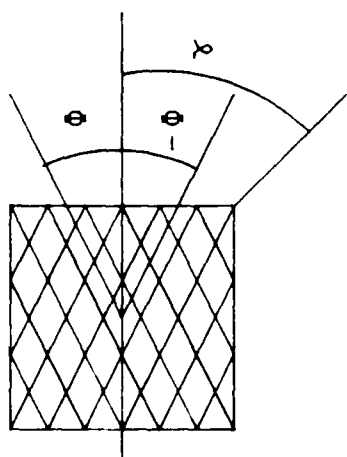


FIG.:127



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \times (1/9)
 Σ (0/1)

$\Phi = 75$

$\alpha_{22}h, (TP\sigma)^{-1}$

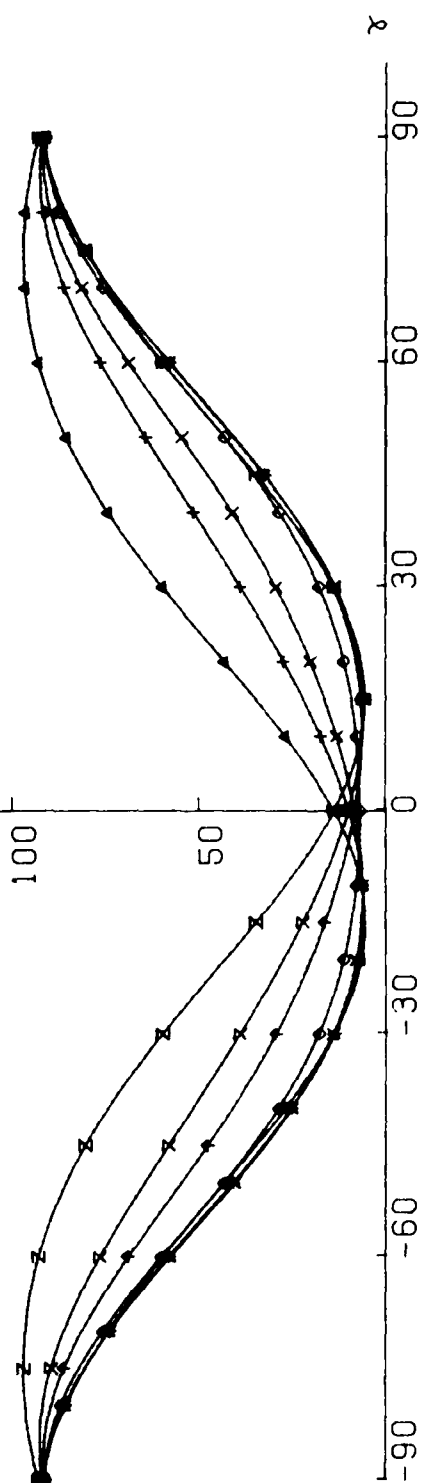
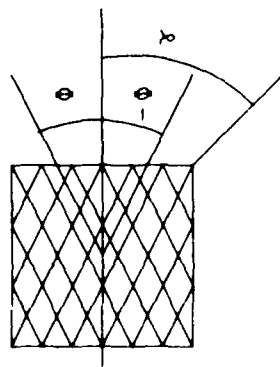


FIG.:128



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\chi = -75$

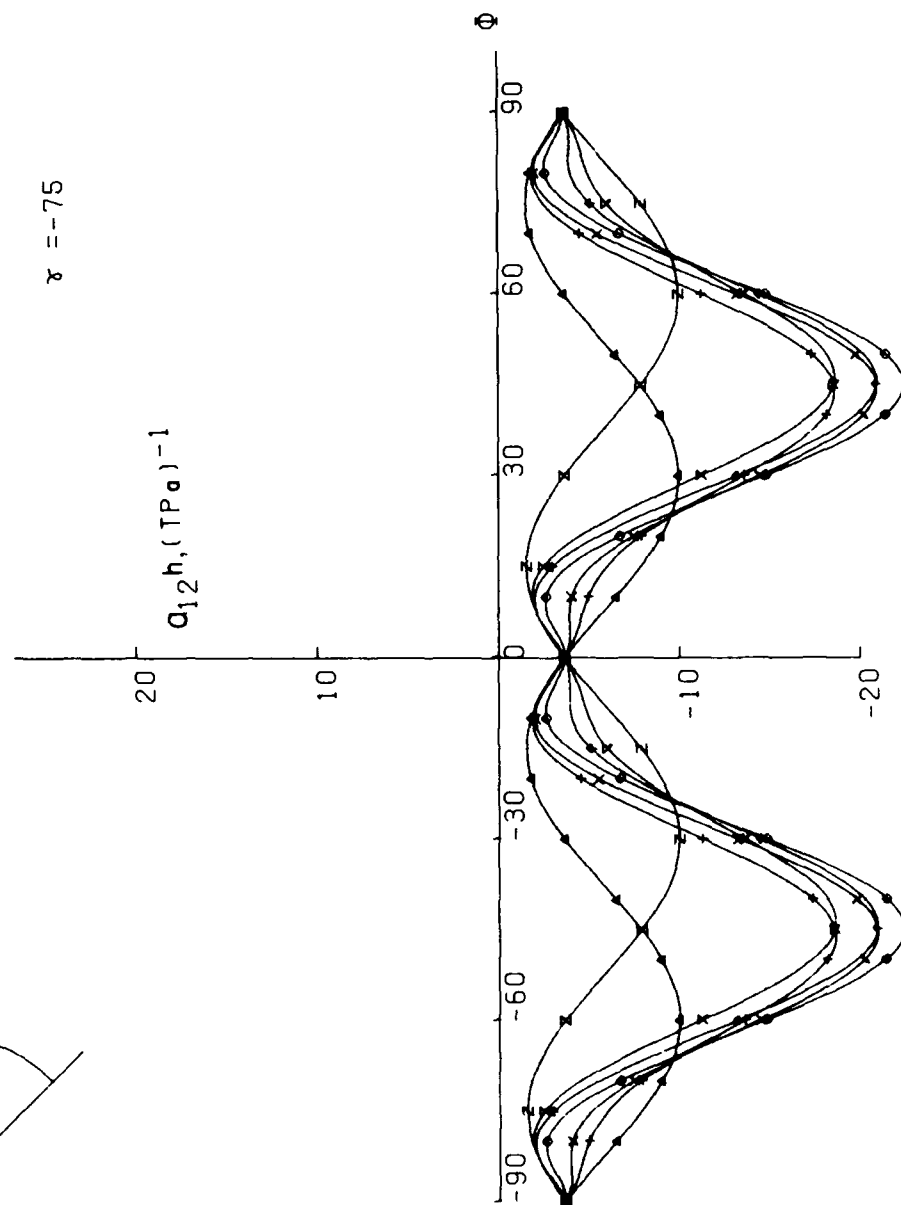
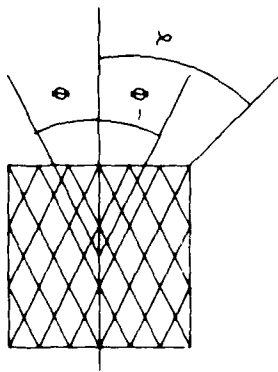


FIG.: 129



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 ∇ (0/1)
 $\chi = -60$

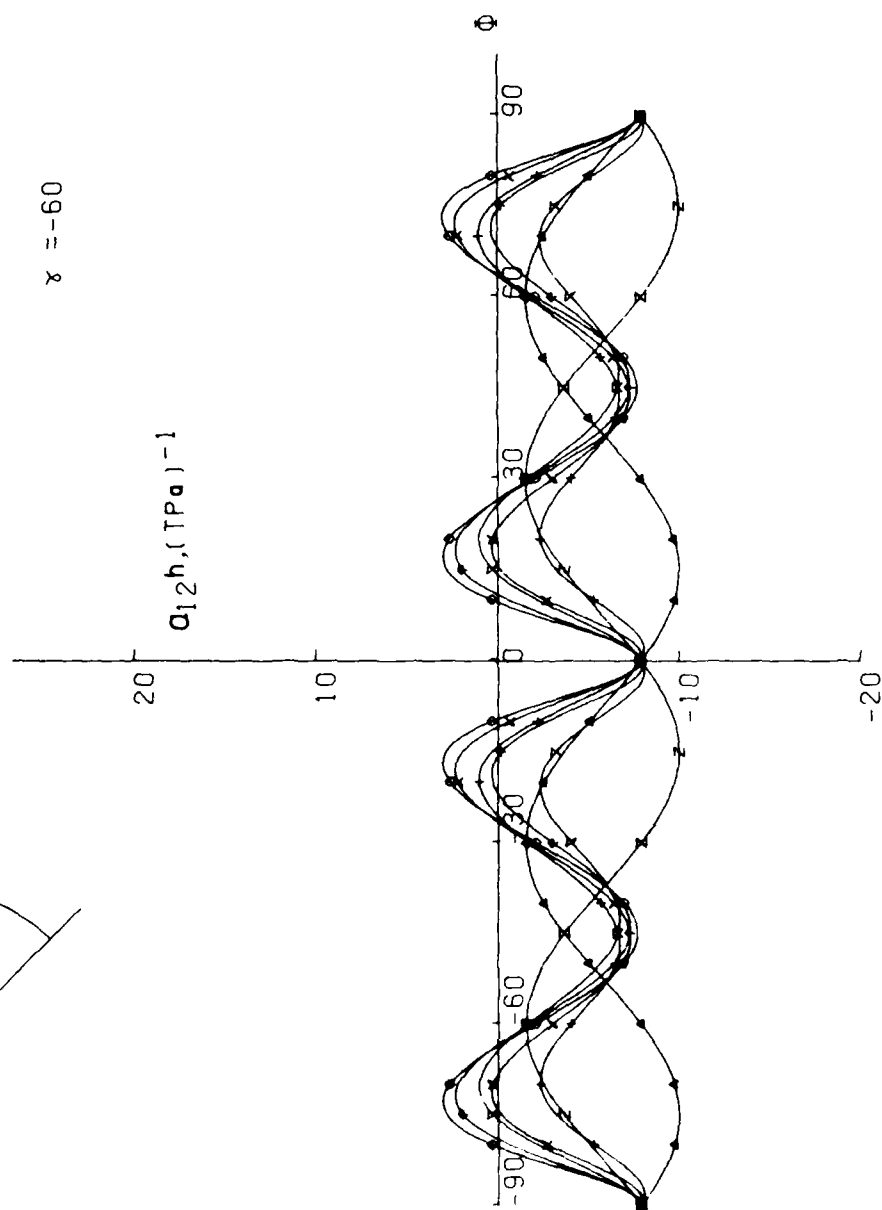
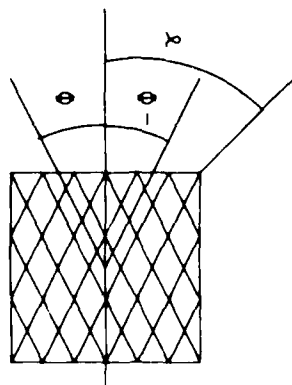


FIG.:130



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = -45$

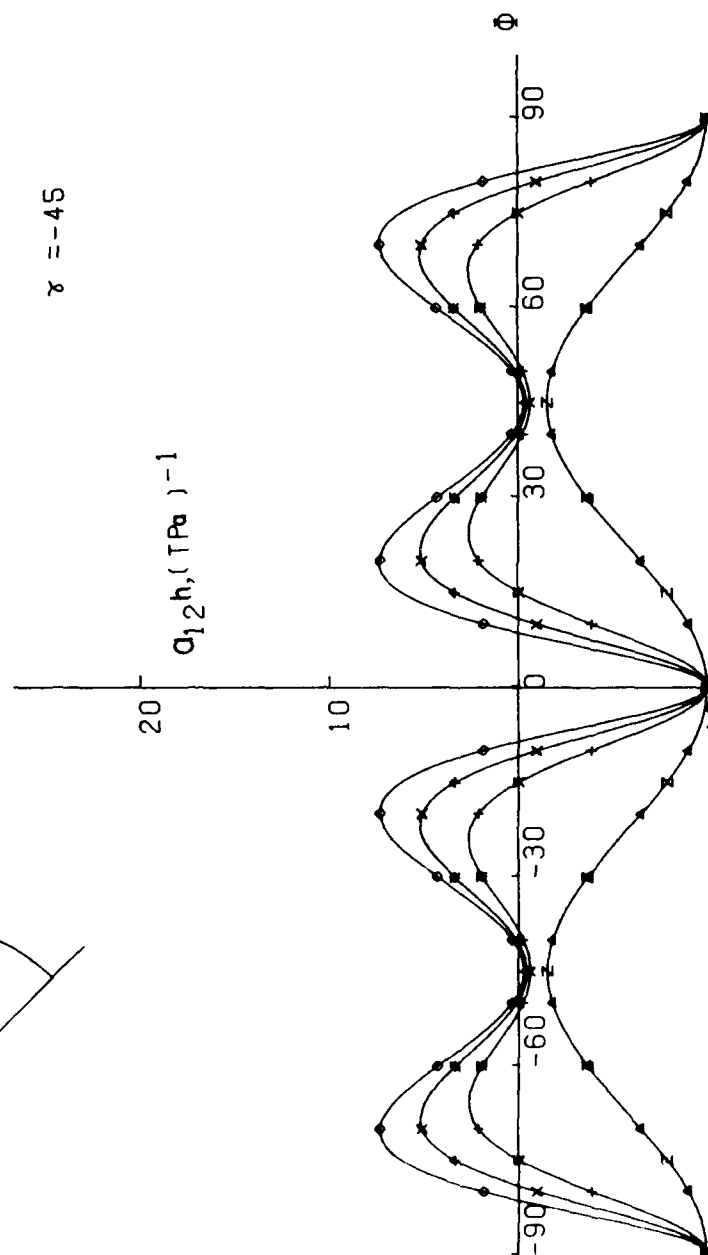
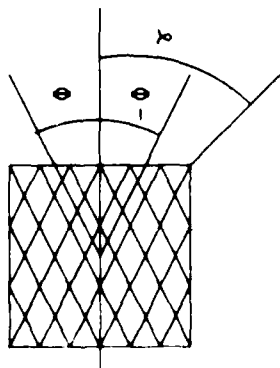


FIG.:131



$\phi / -\phi$

Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
\oplus	(1/4)
\times	(1/9)
z	(0/1)

$\chi = -30$

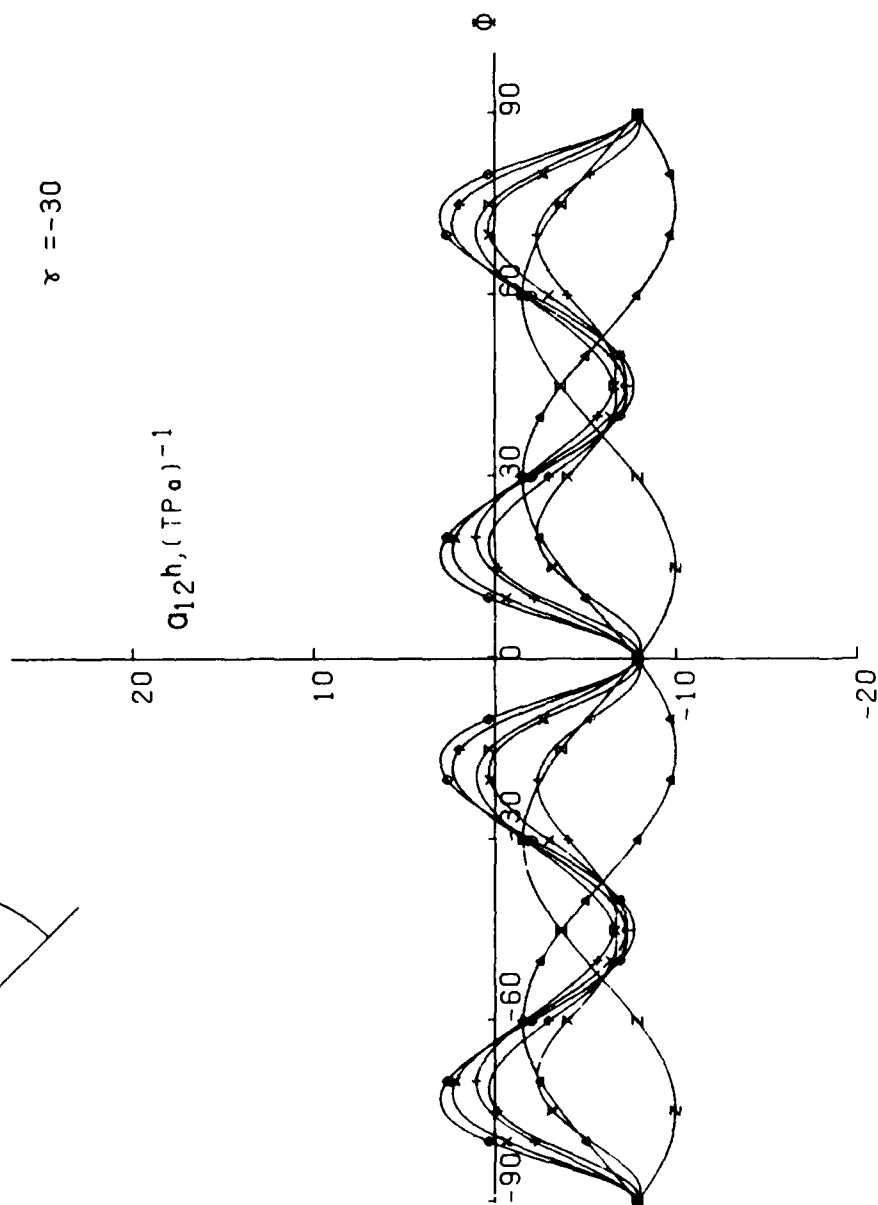
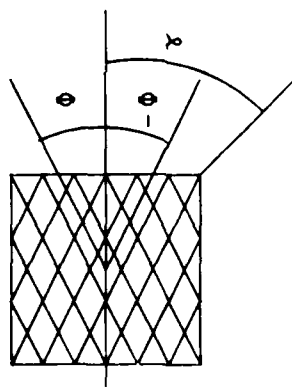


FIG.:132



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = -15$

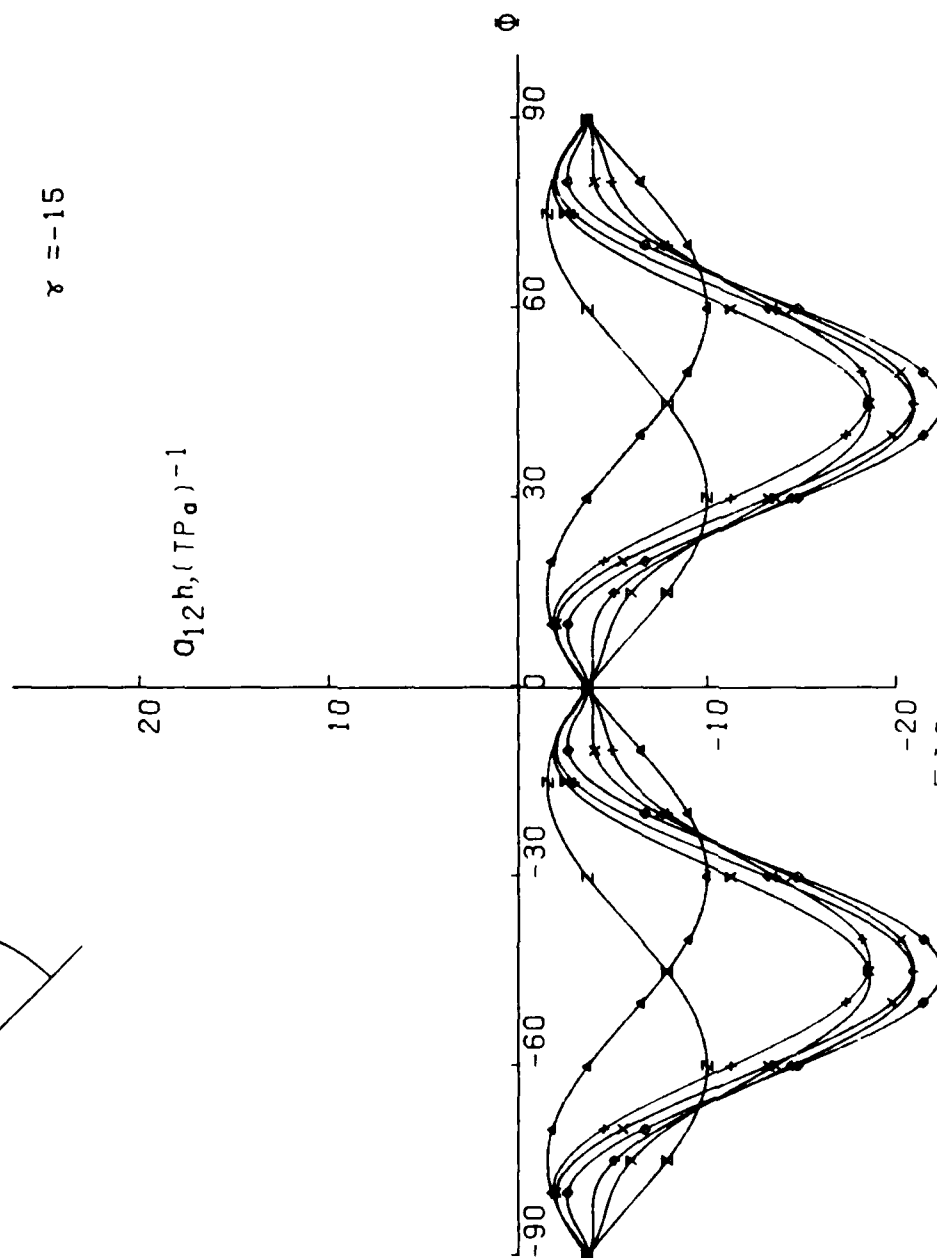
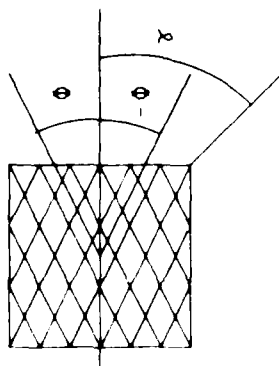


FIG.:133



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = 0$

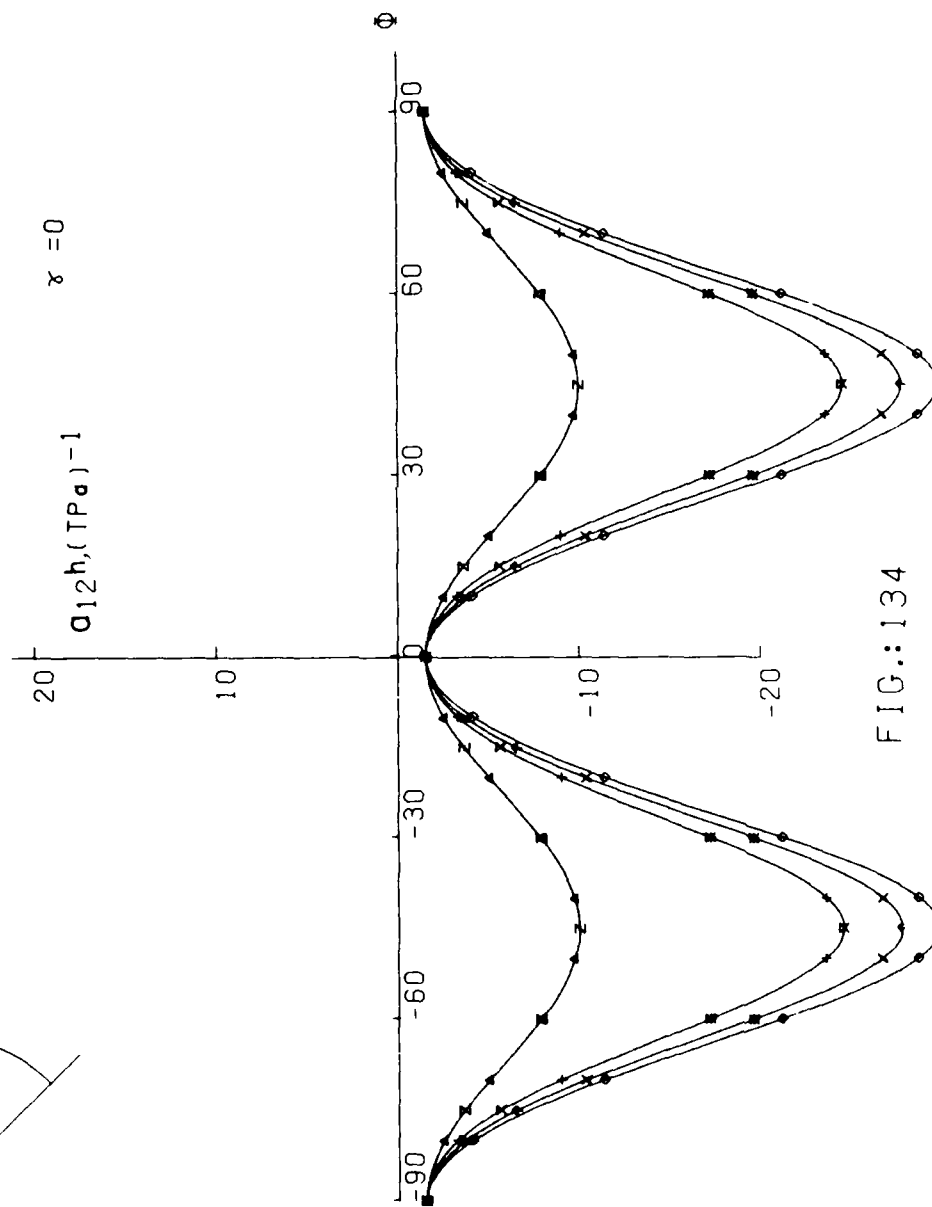
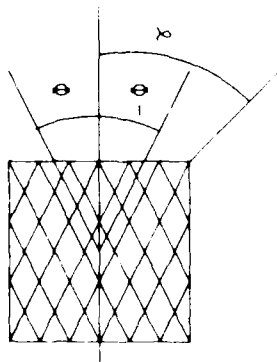


FIG.:134



Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\chi = 15$

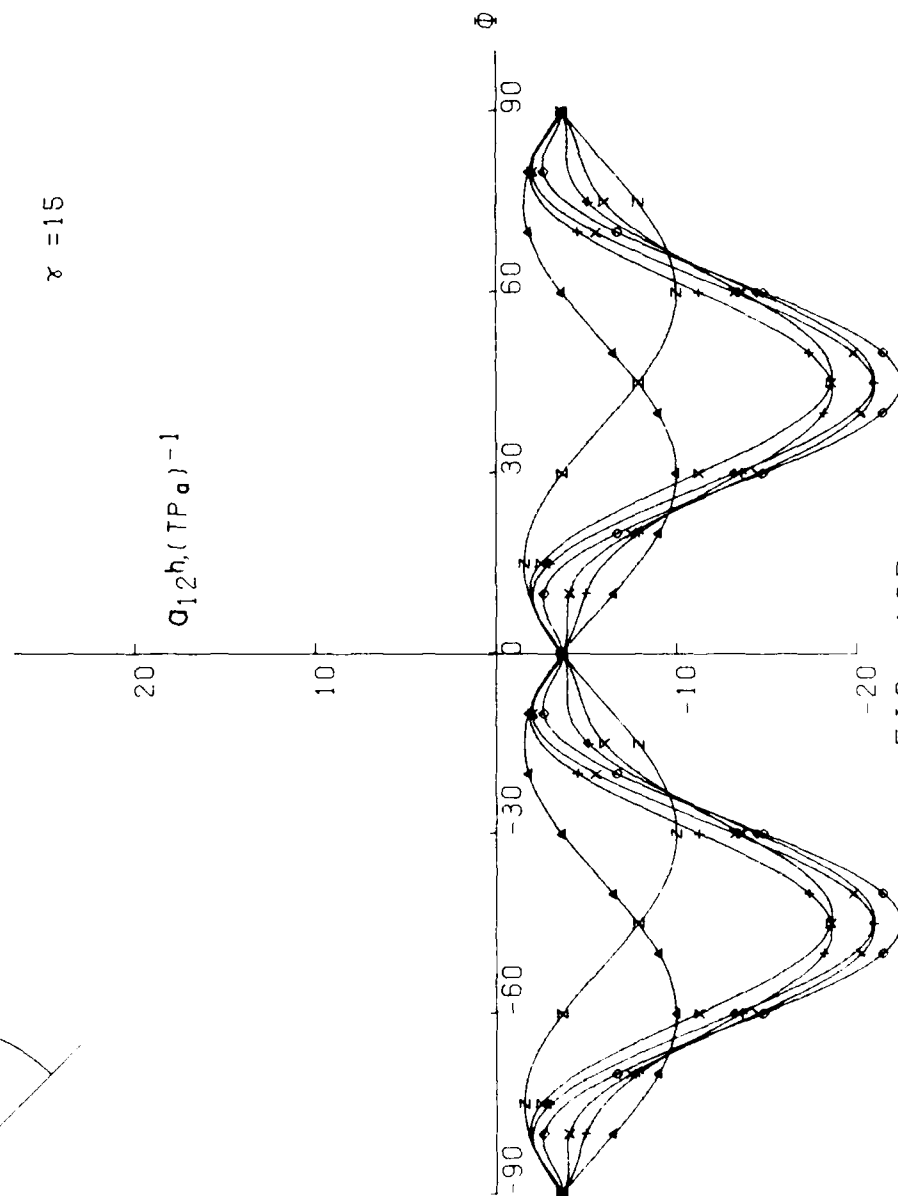
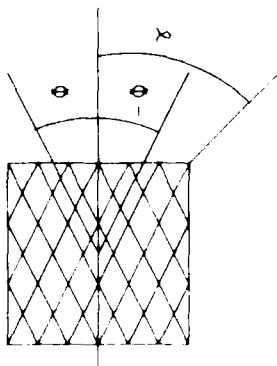


FIG.:135



$\Phi / -\Phi$

Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
∇	(1/4)
x	(1/9)
Z	(0/1)

$\alpha = 30$

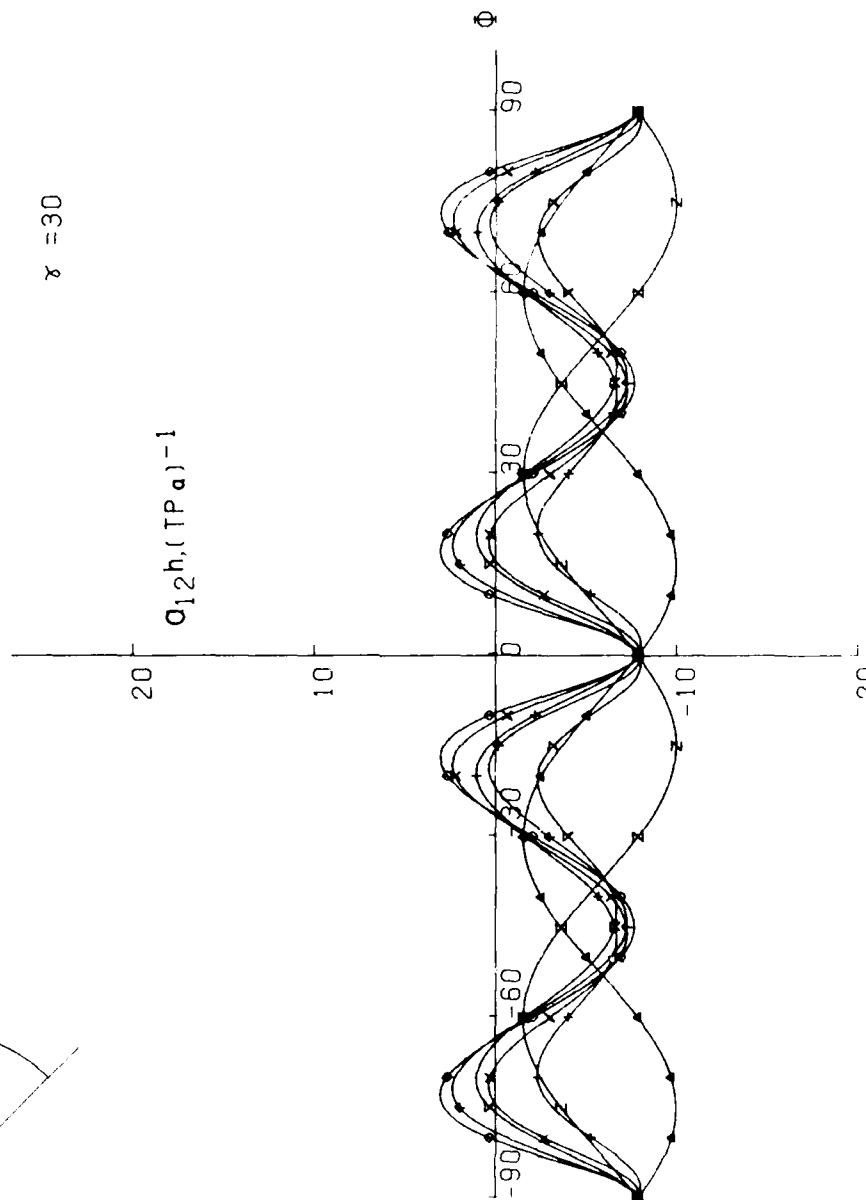
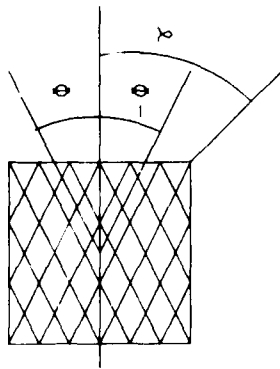


FIG.: 136



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\chi = 45$

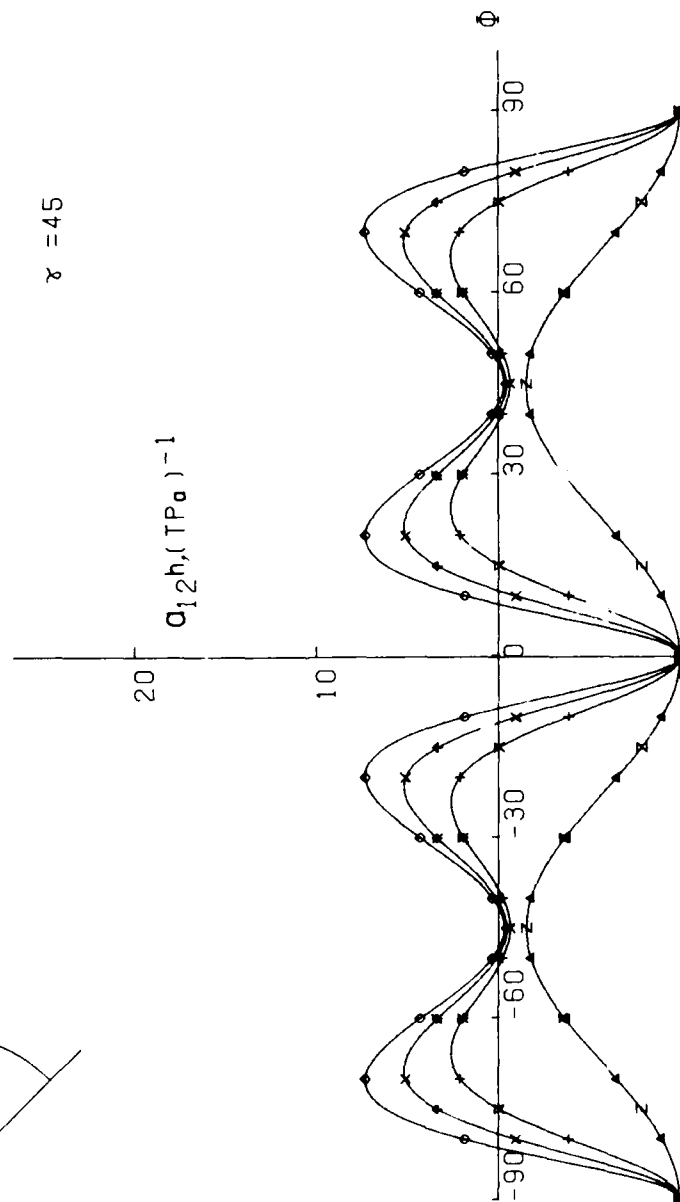
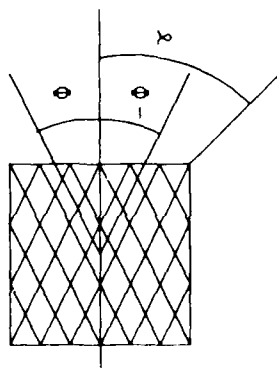


FIG.:137



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\chi = 60$

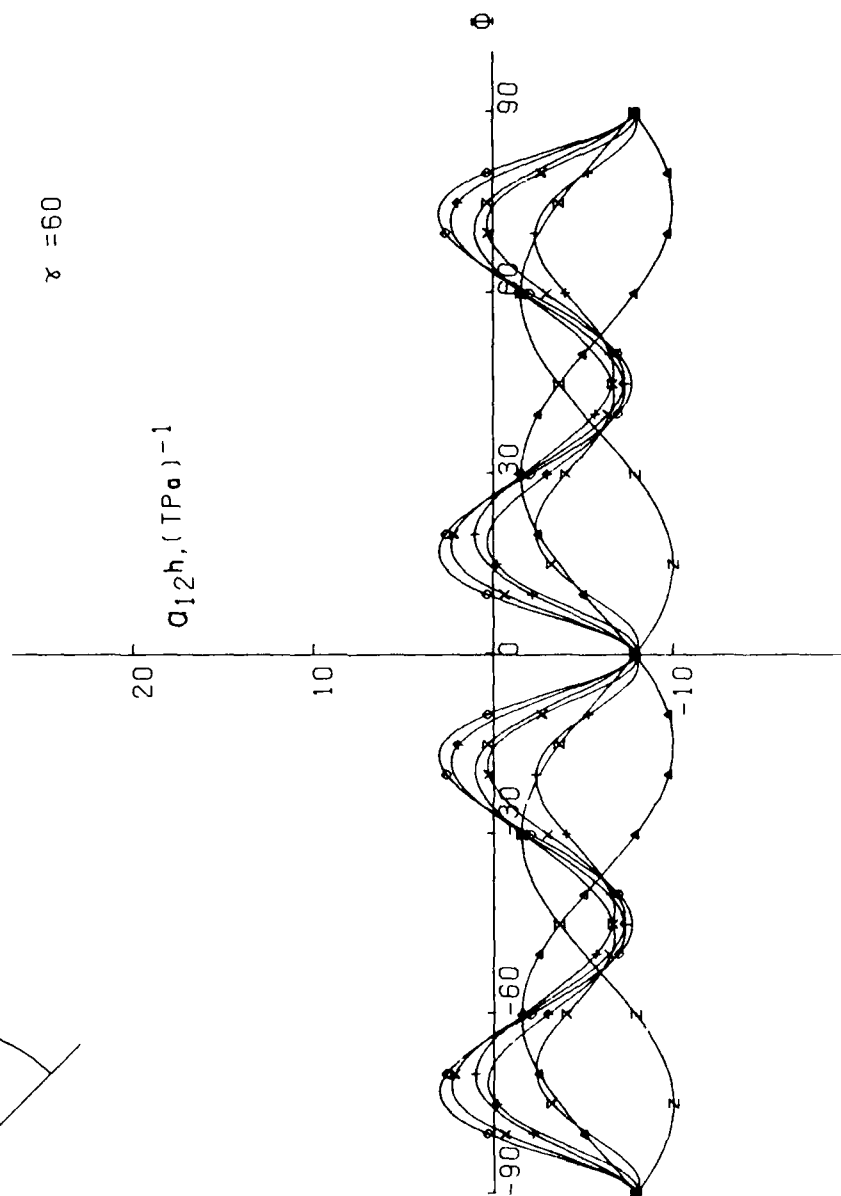
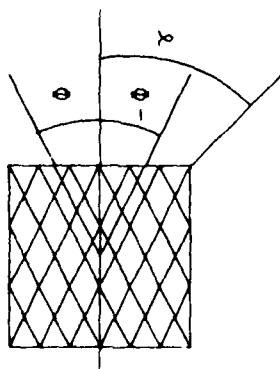


FIG.: 138



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \star (1/4)
 ∇ (1/9)
 Z (0/1)

$\chi = 75$

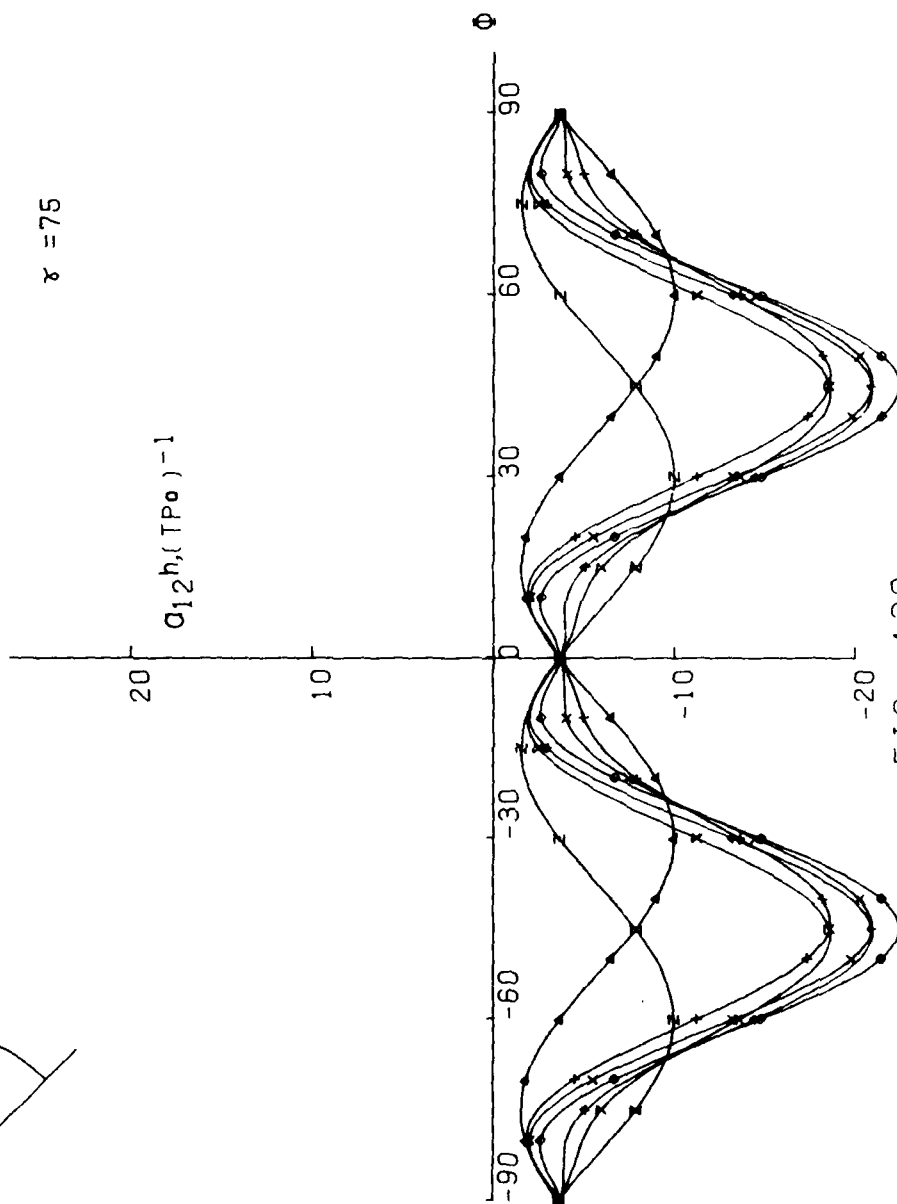
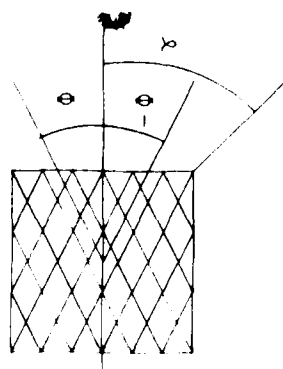


FIG.:139



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \times (1/9)
 Σ (0/1)

$\phi = 15$

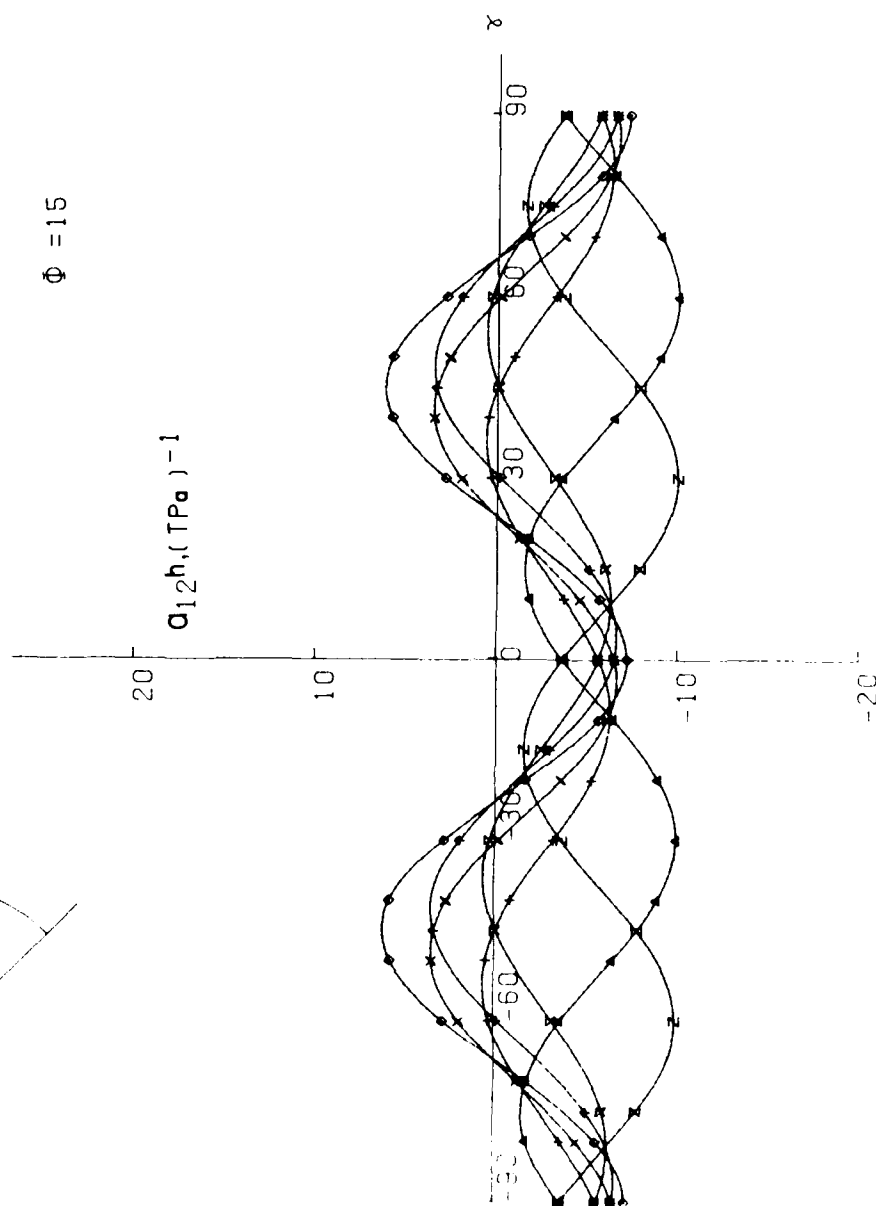


FIG.:140

$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Z (0/1)
 $\phi = 30$

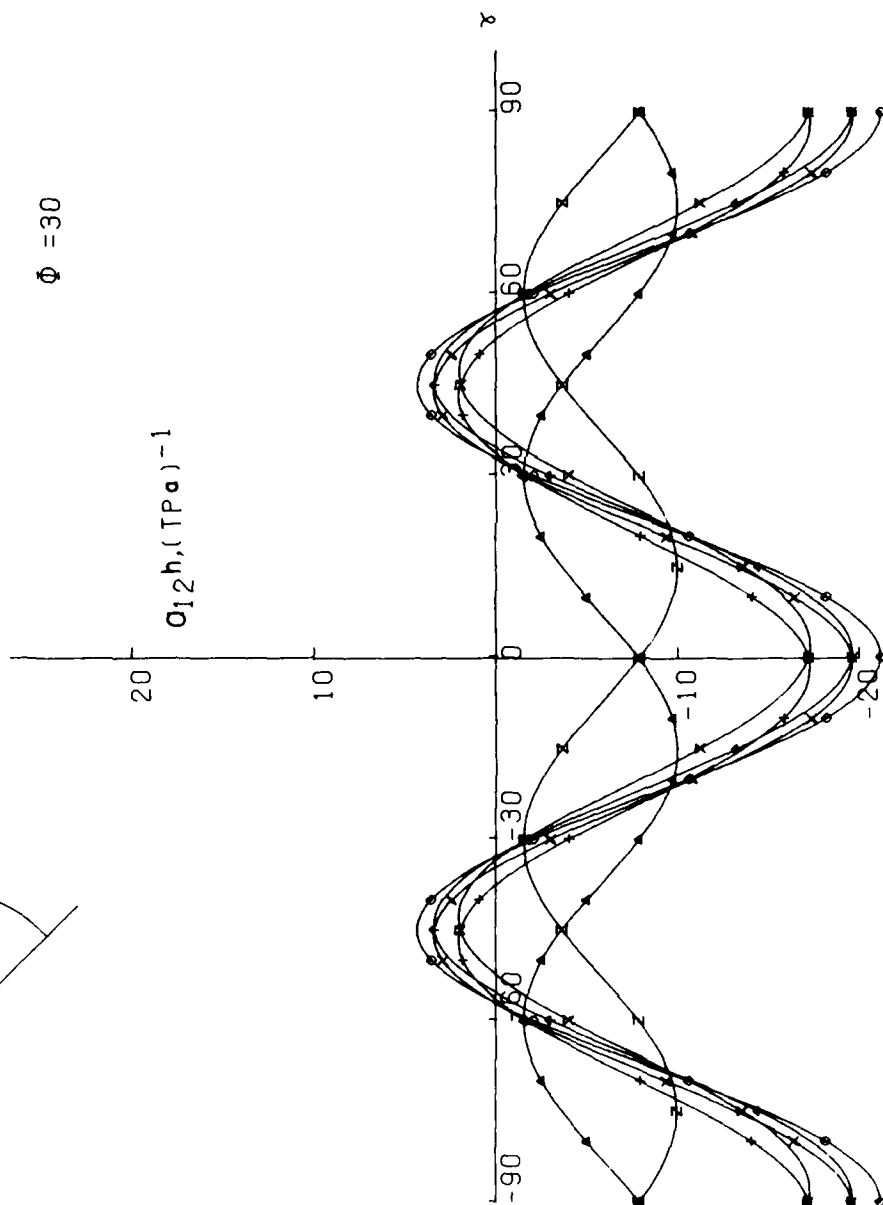
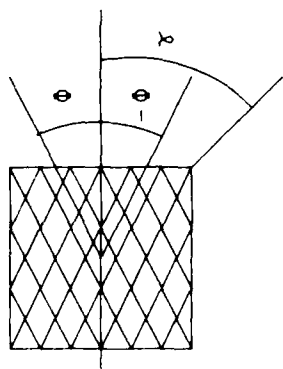
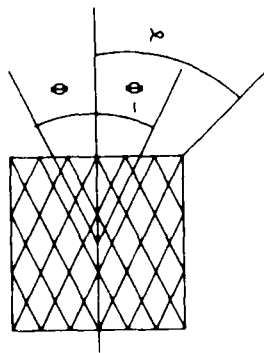


FIG.:141



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\phi = 45$

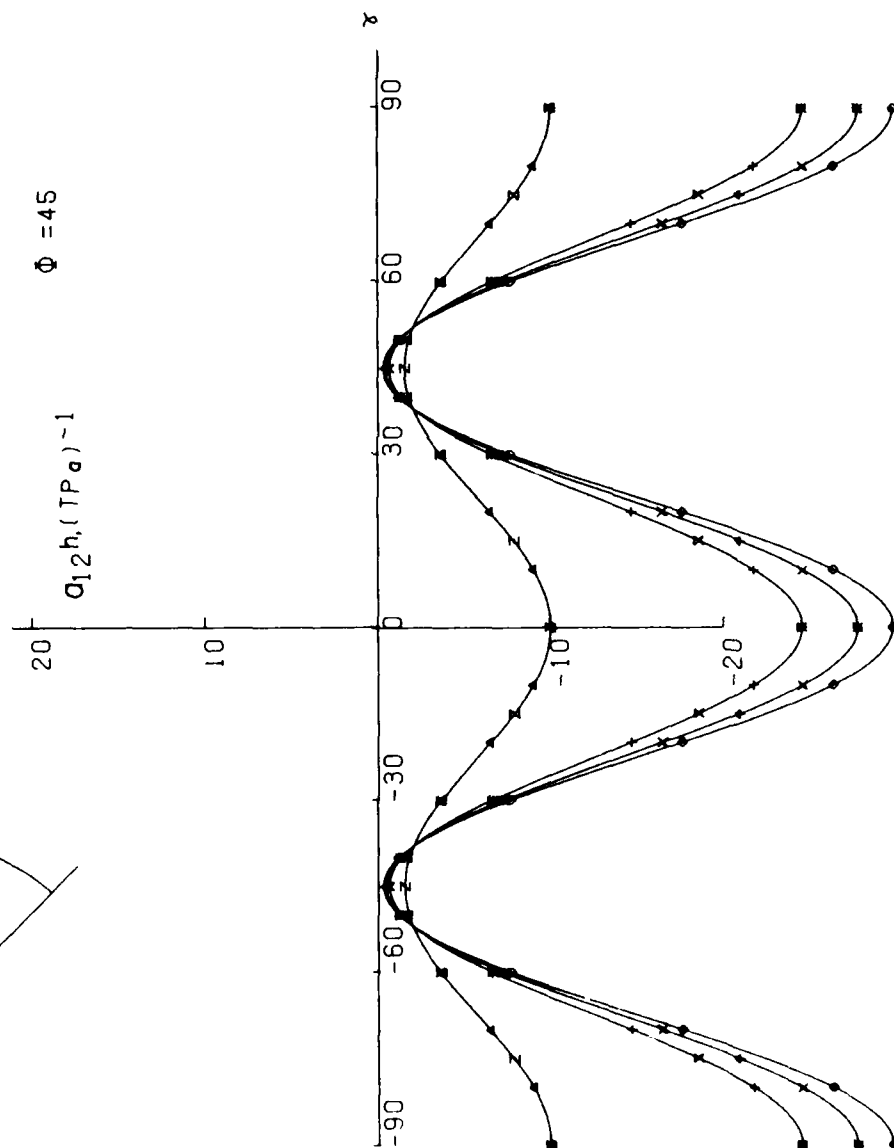
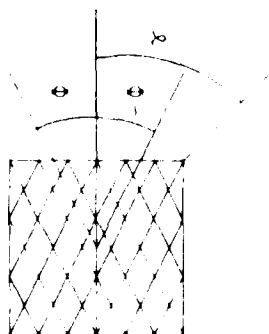


FIG.: 142



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 \square (0/1)
 $\Phi = 60$

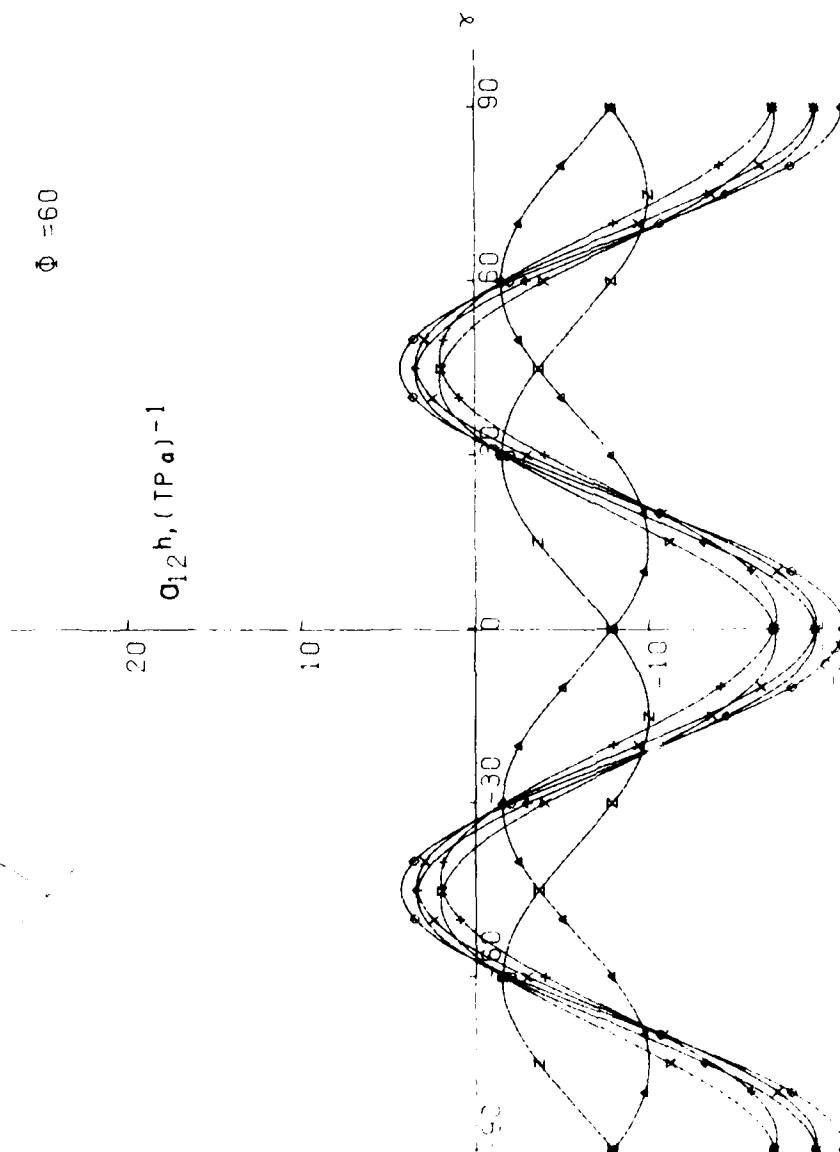
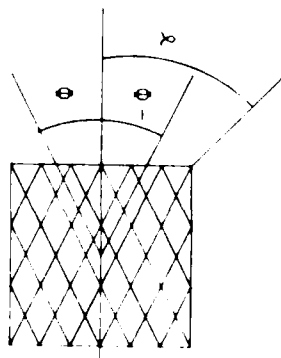


FIG.:143



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\Phi = 75$

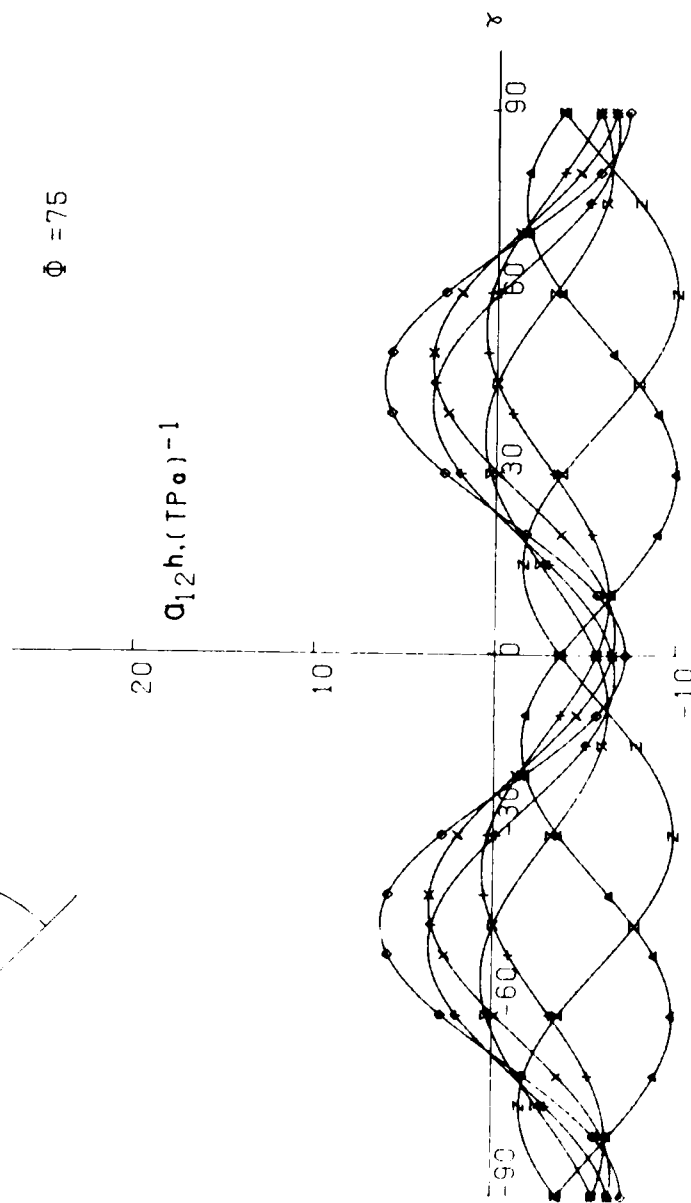
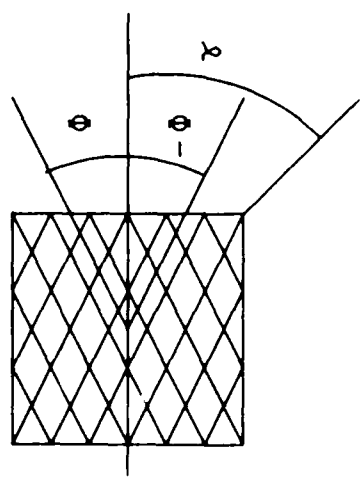


FIG.:144



- $\Phi / -\Phi$
- Δ (1/0)
 - $+$ (9/1)
 - \times (4/1)
 - \diamond (1/1)
 - \oplus (1/4)
 - \otimes (1/9)
 - Σ (0/1)

$a_{66} h, (TPa)^{-1}$

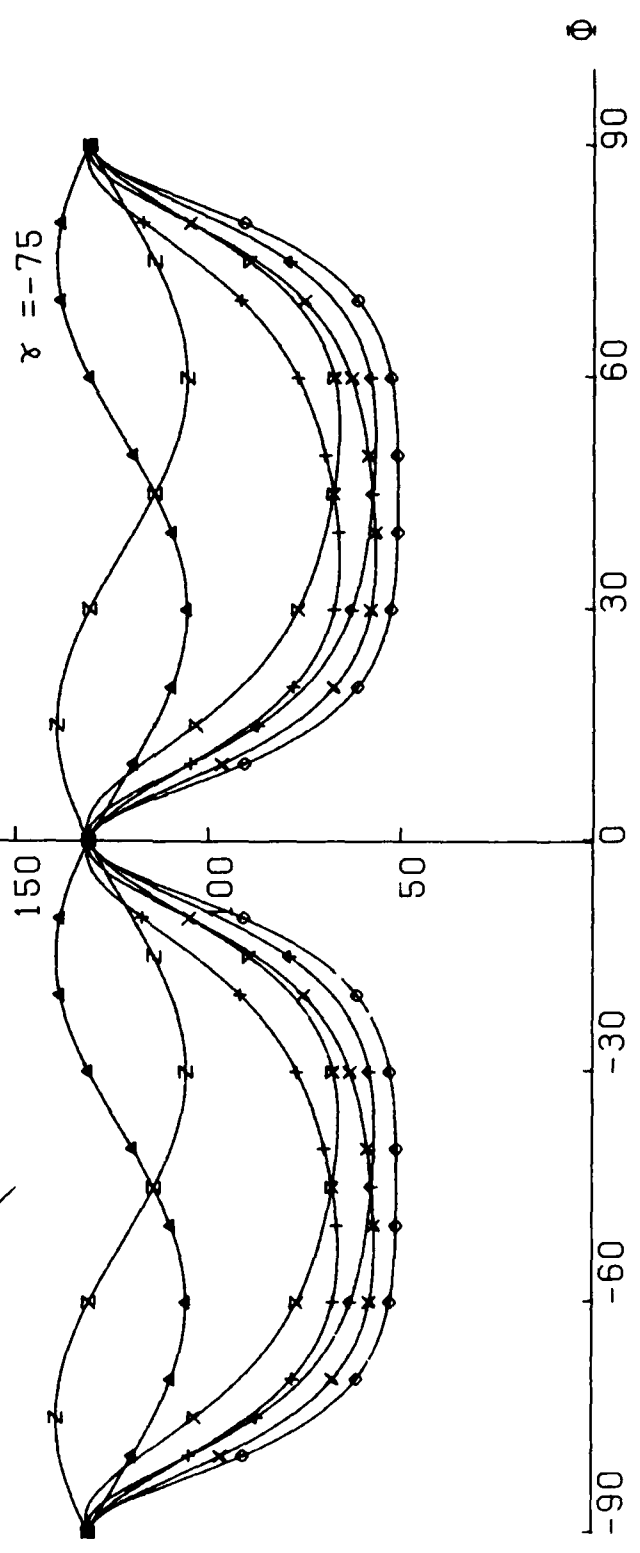
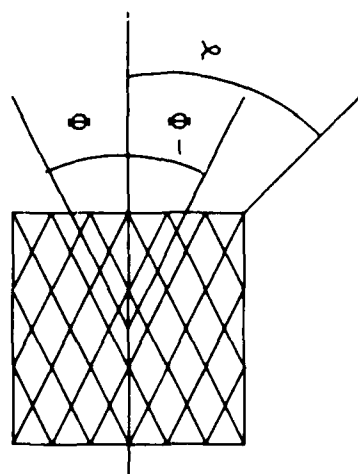


FIG.:145

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \times (1/9)
 Σ (0/1)



$\sigma_{66} h_i (\text{TPa})^{-1}$

$\chi = -60$

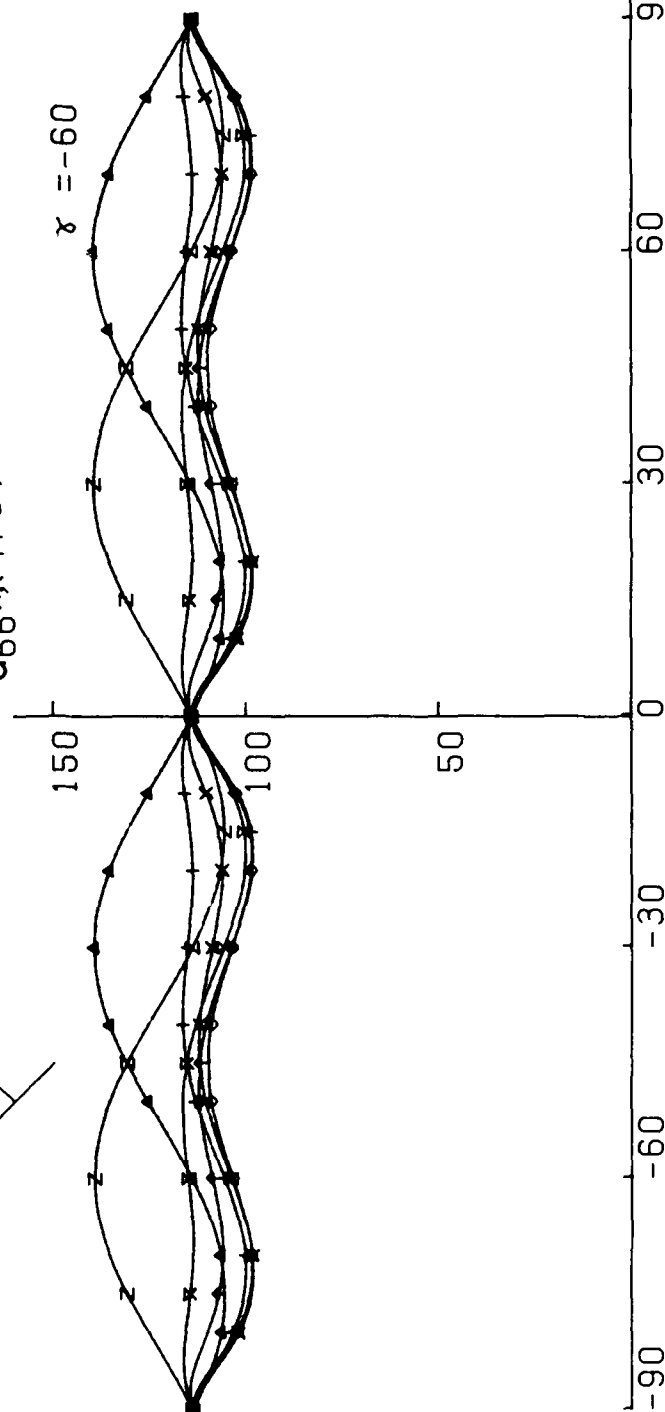


FIG.:146

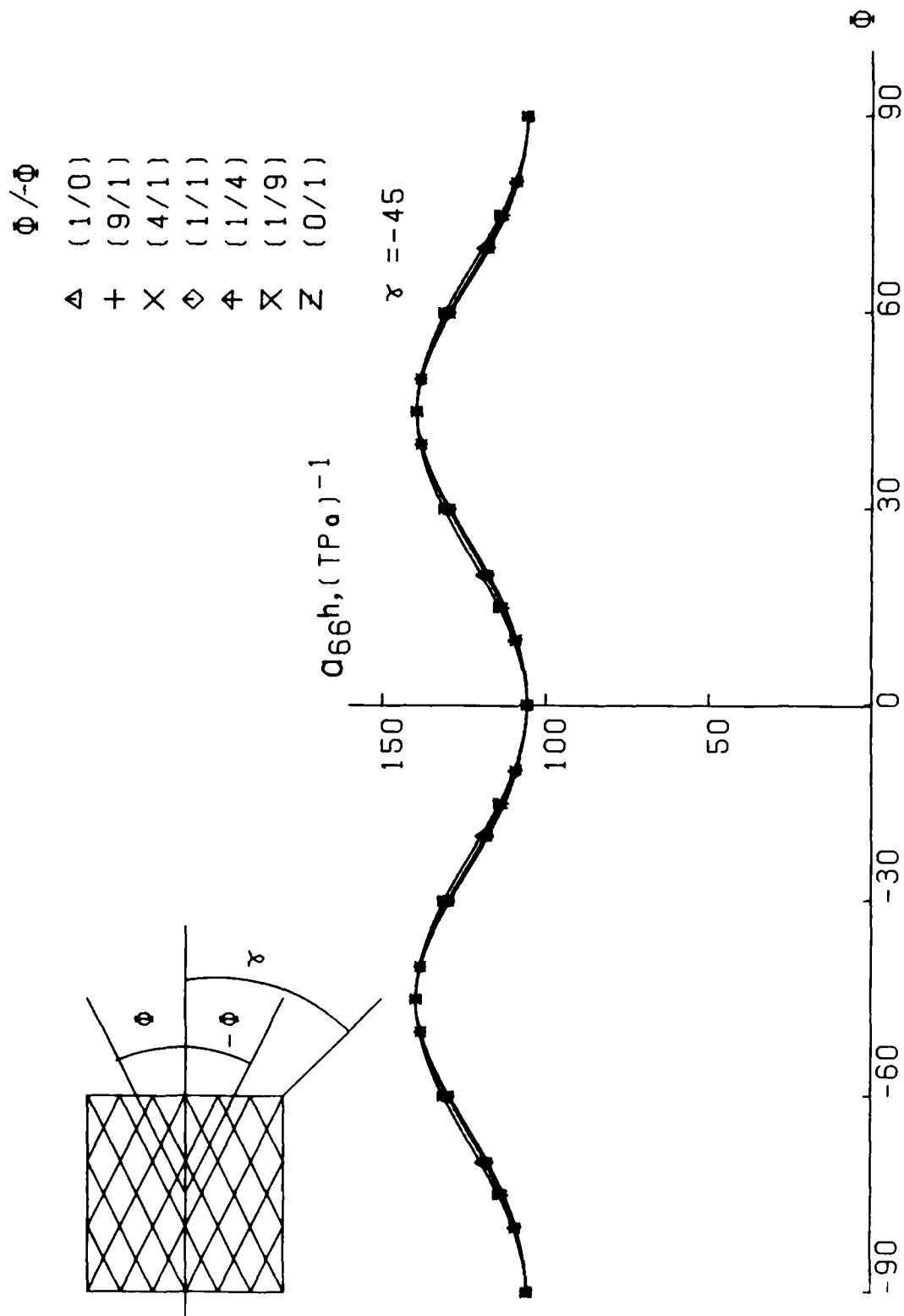


FIG.:147

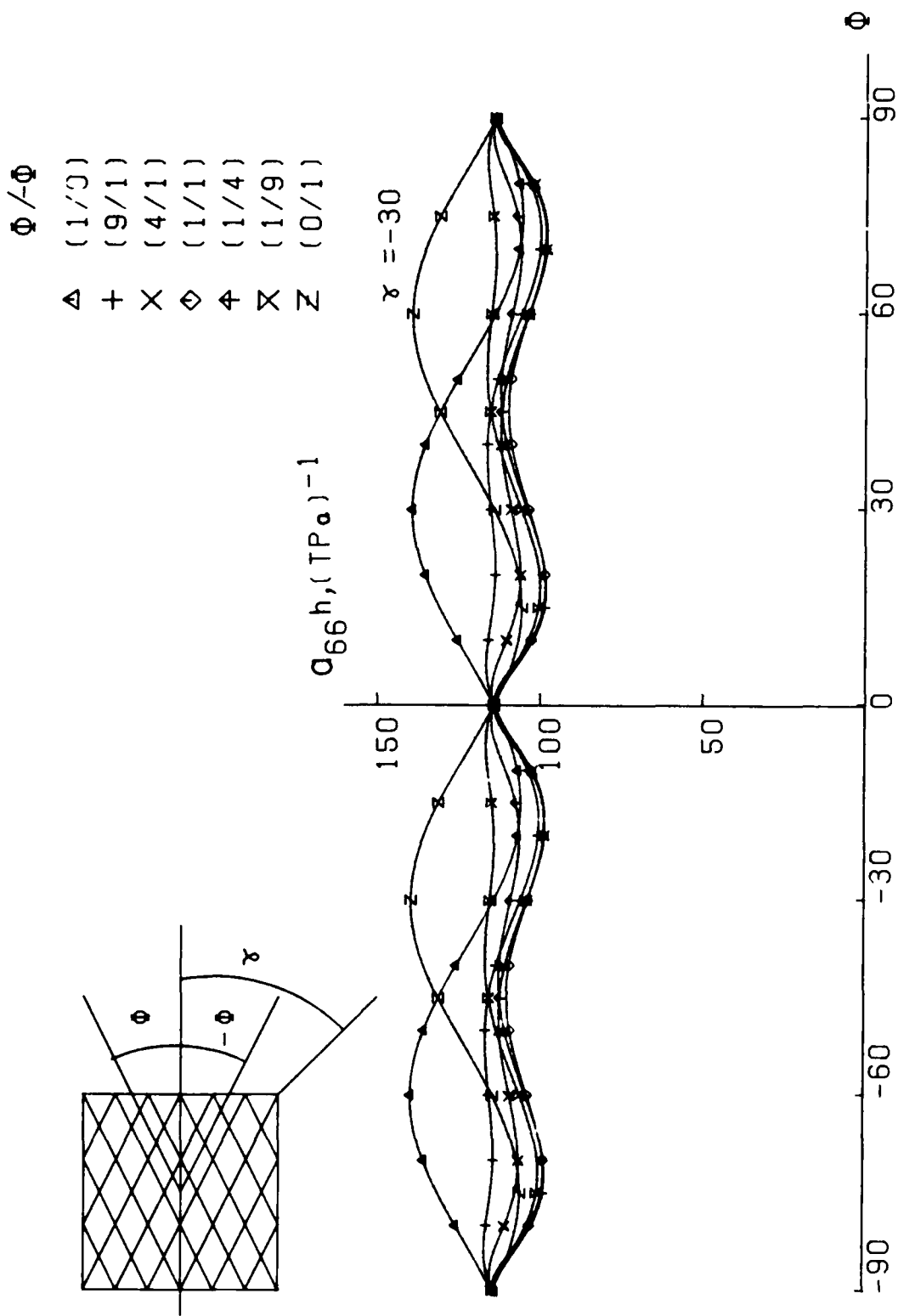
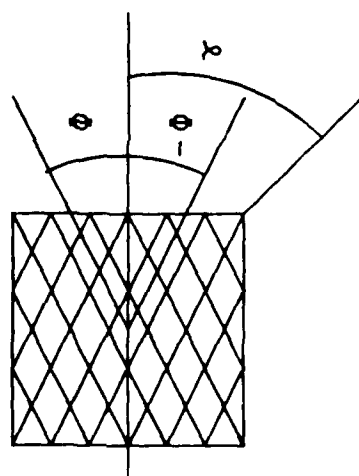


FIG.:148

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)



$Q_{66}h, (TPa)^{-1}$

$\gamma = -15$

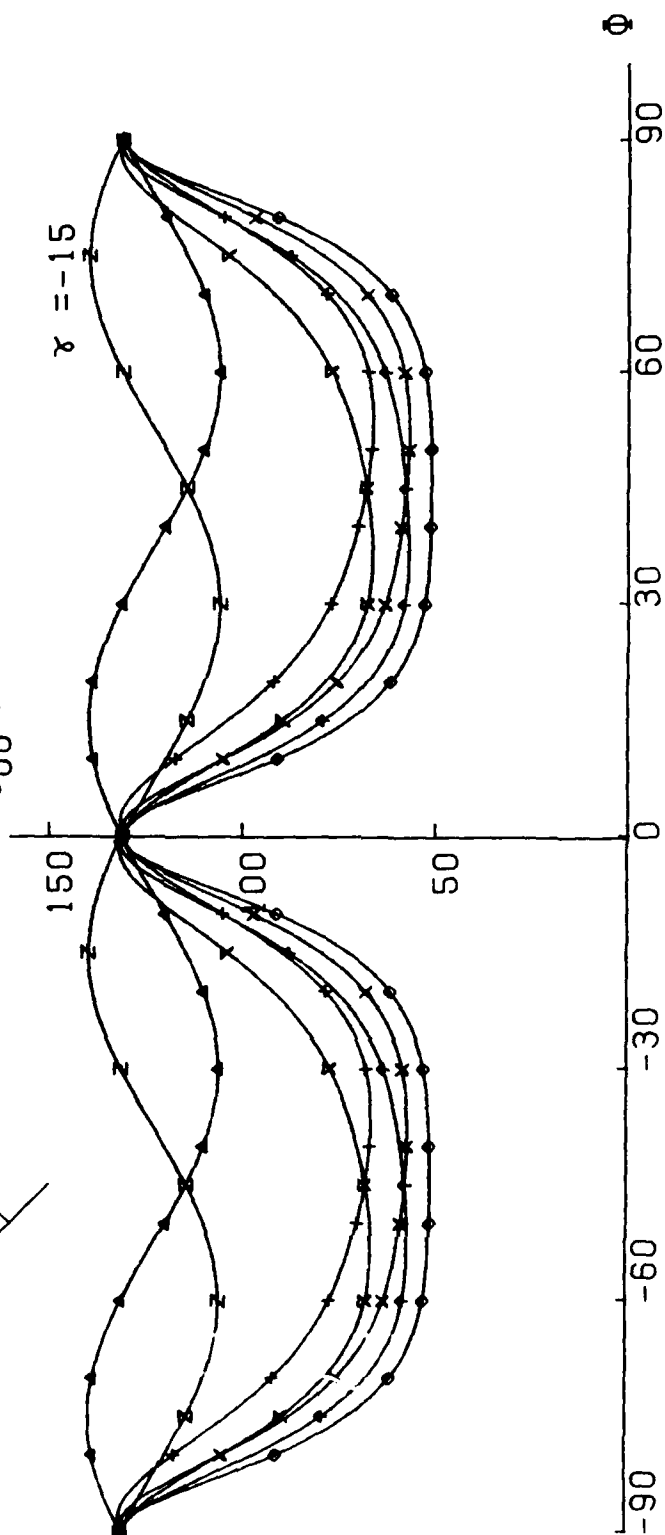


FIG.:149

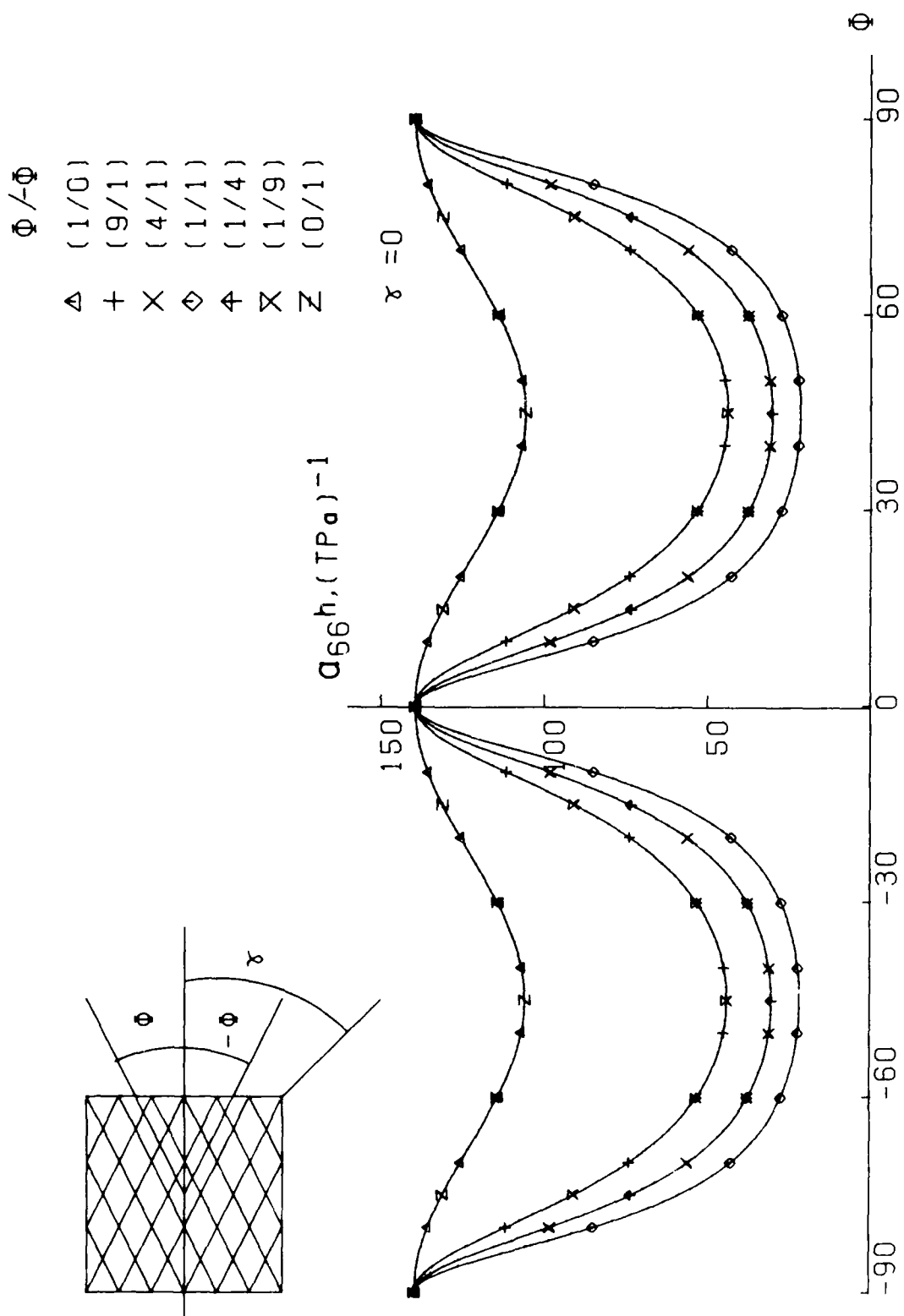


FIG.:150

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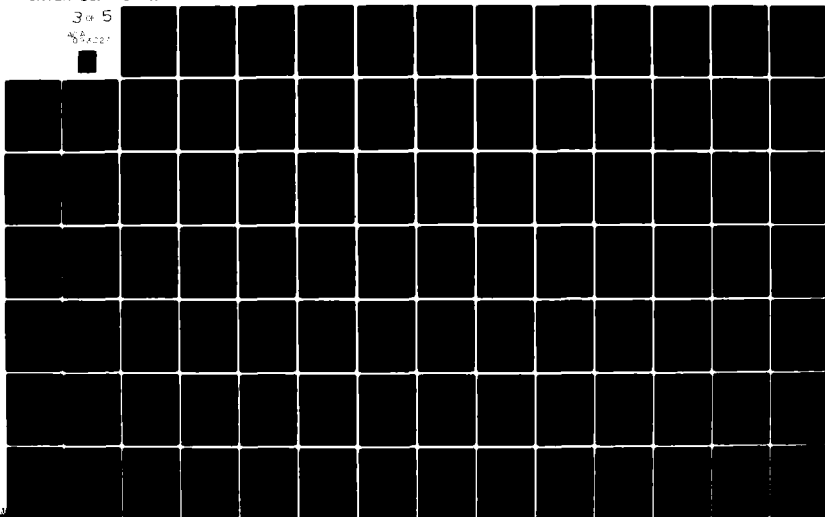
AIR FORCE WRIGHT AERONAUTICAL LABS WRIGHT-PATTERSON AFB OH F/G 11/4
ELASTIC PROPERTIES OF T300/5208 BIDIRECTIONAL SYMMETRIC LAMINAT--ETC(U)
SEP 80 S R SONI

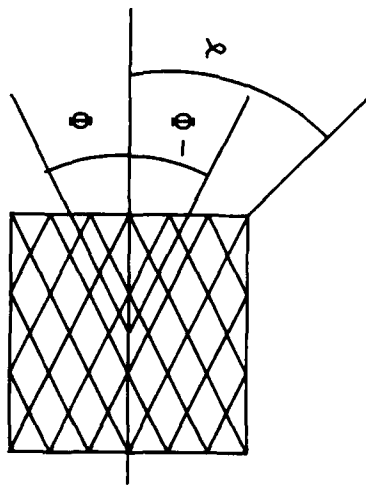
UNCLASSIFIED AFWAL-TR-80-4111

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Φ/Φ

Δ	(1/0)
+	(9/1)
X	(4/1)
\diamond	(1/1)
4	(1/4)
X	(1/9)
Z	(0/1)

$Q_{66}h, (TP\sigma)^{-1}$

$\chi = 15$

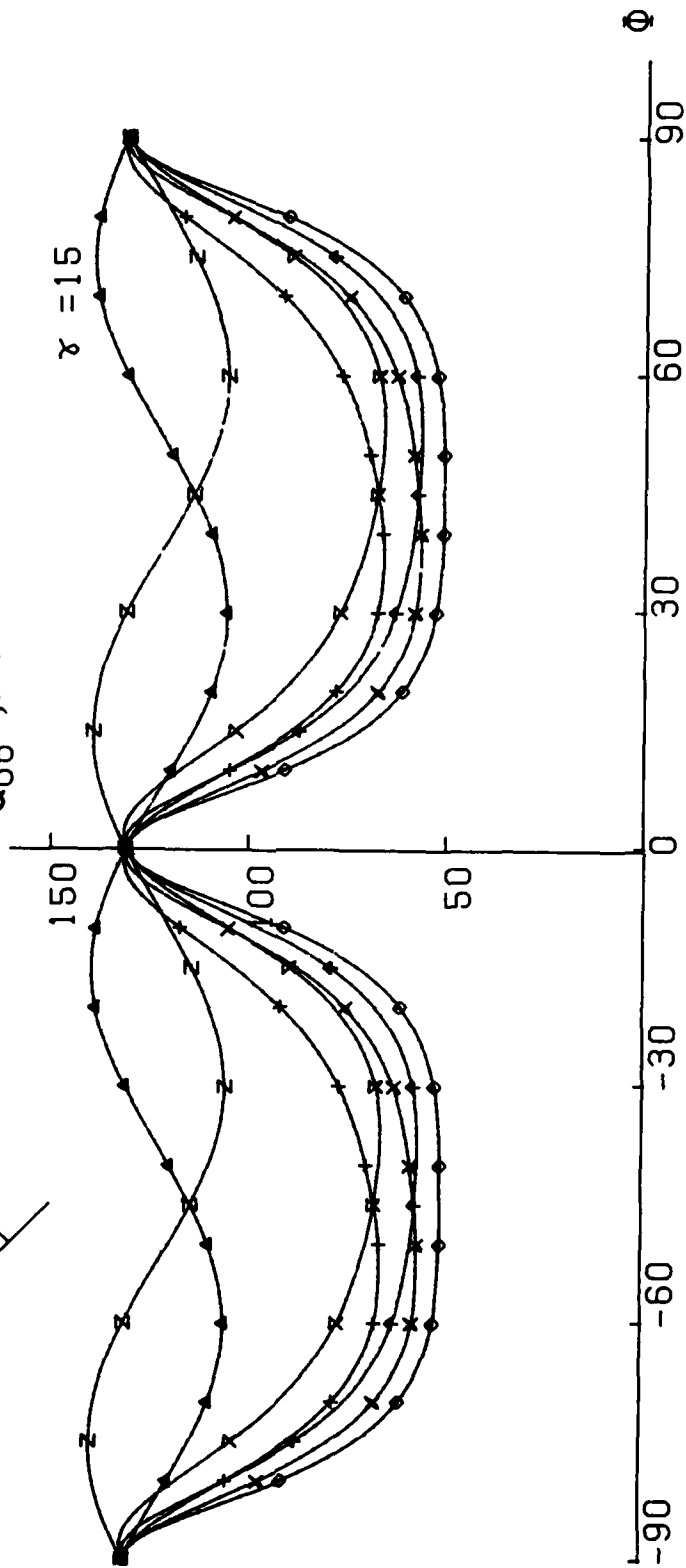
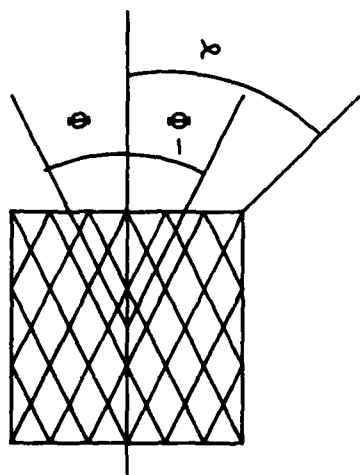


FIG.: 151



ϕ/ϕ	
Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
∇	(1/4)
\times	(1/9)
Z	(0/1)

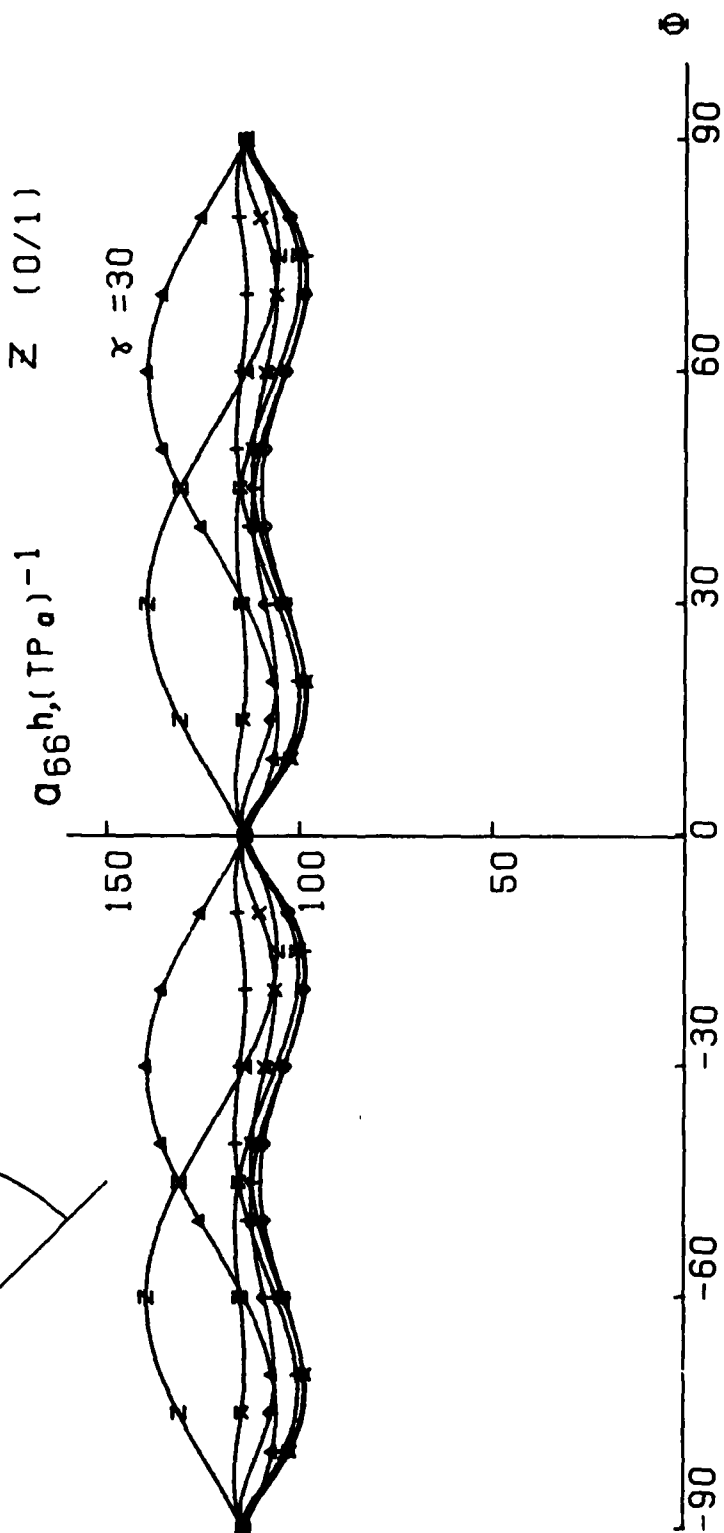
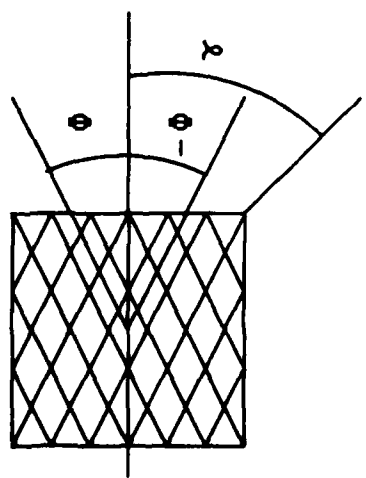


FIG.:152

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)



$Q_{66}h, (TP\sigma)^{-1}$

$\gamma = 45$

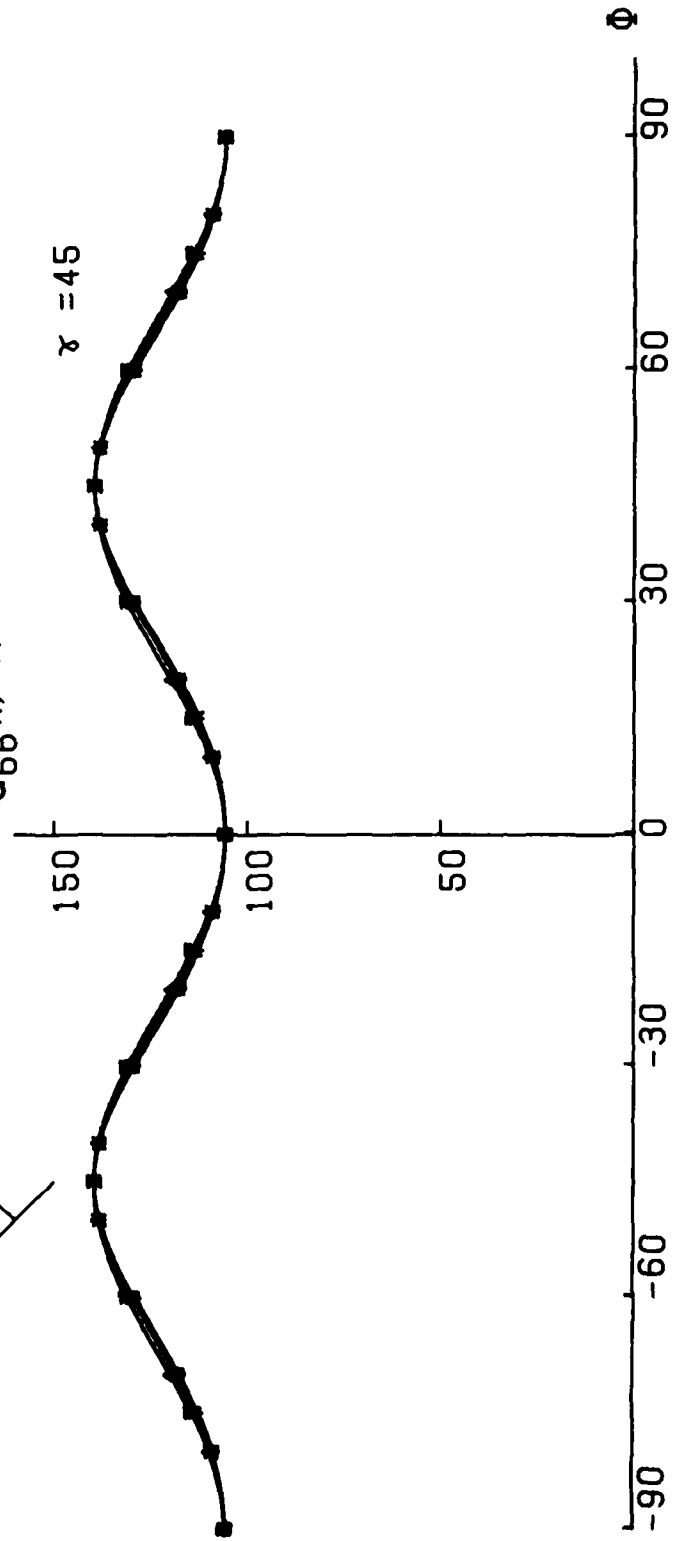


FIG.: 153

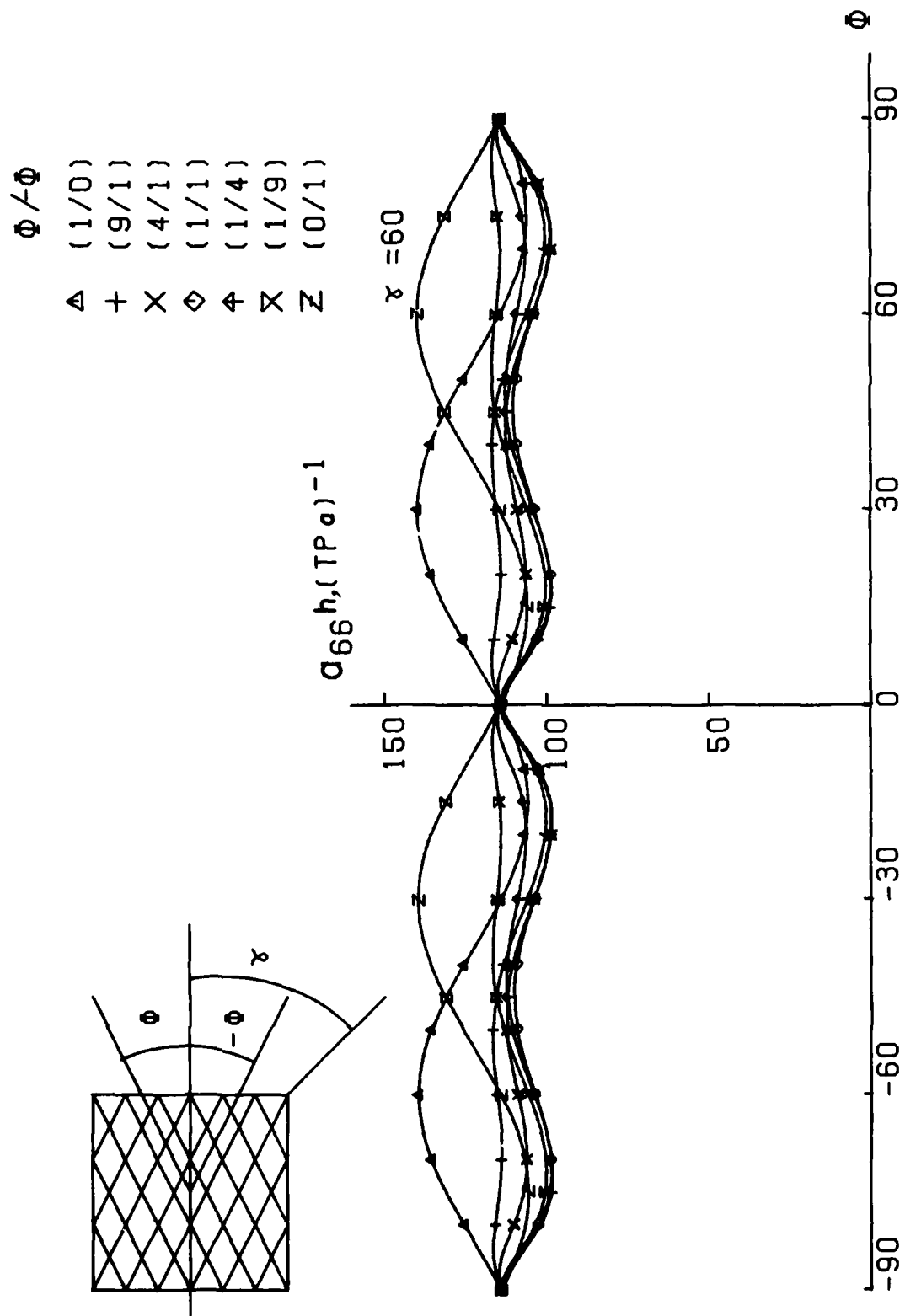
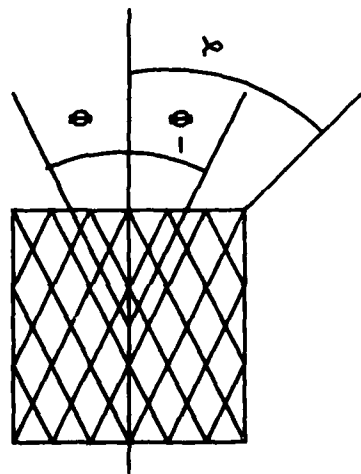


FIG.:154



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 \times (1/9)
 Σ (0/1)

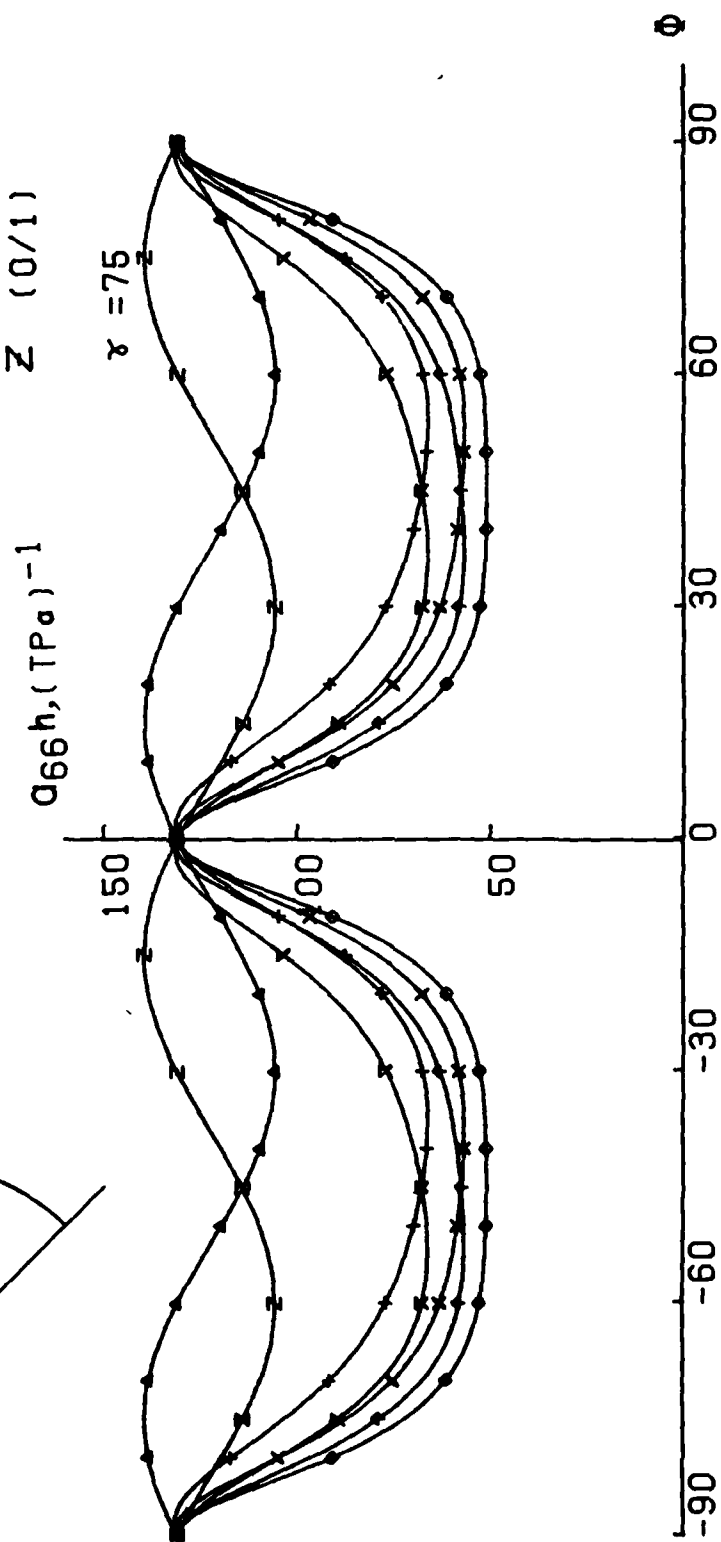
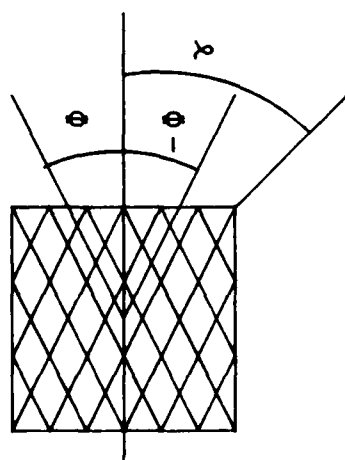
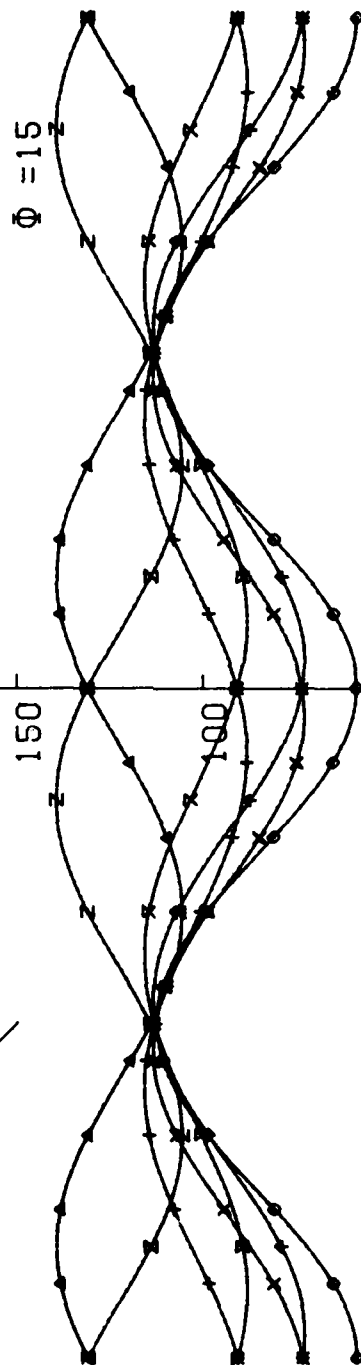


FIG.:155

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)



$a_{66}h, (TP_0)^{-1}$



γ

FIG.: 156

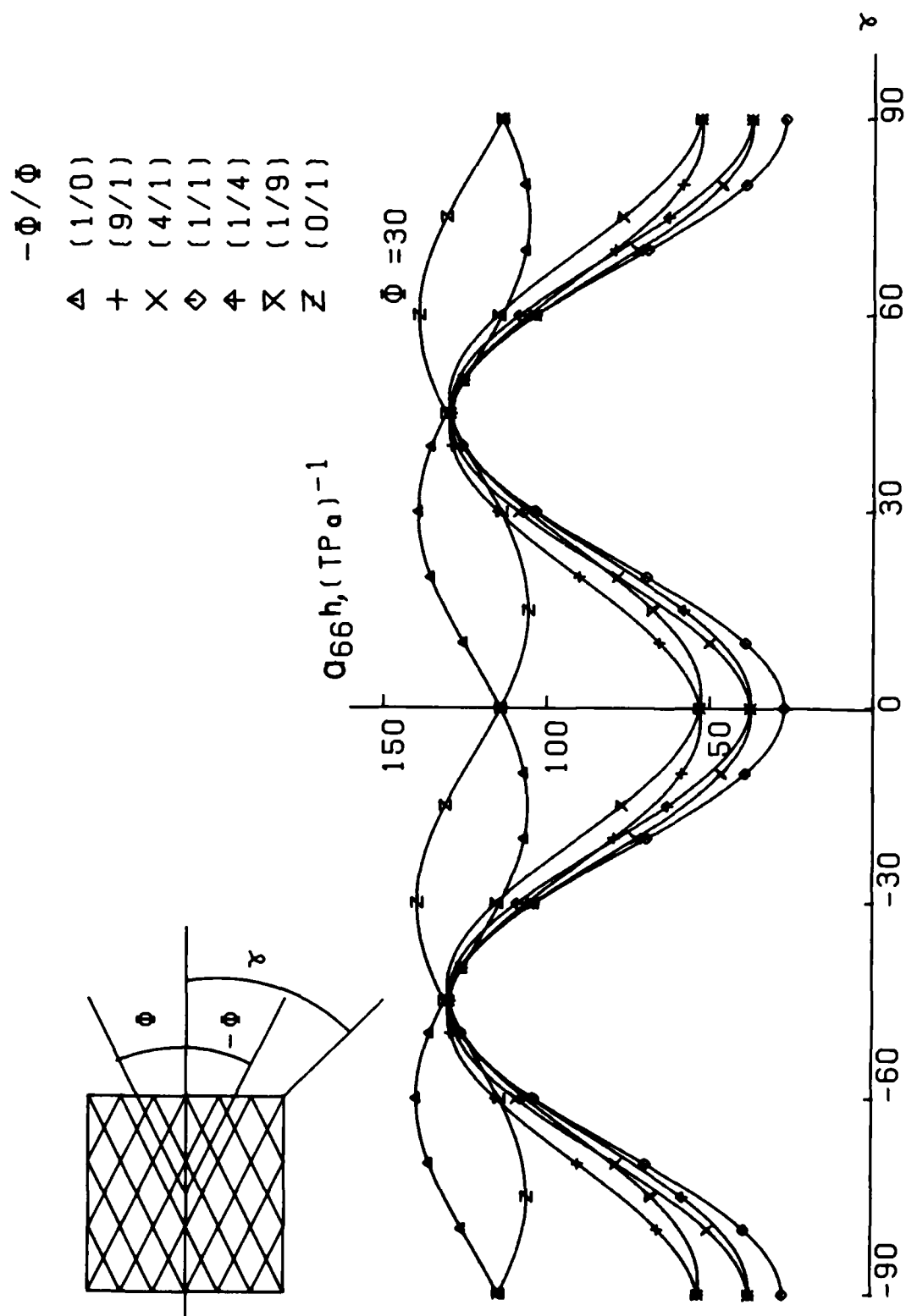
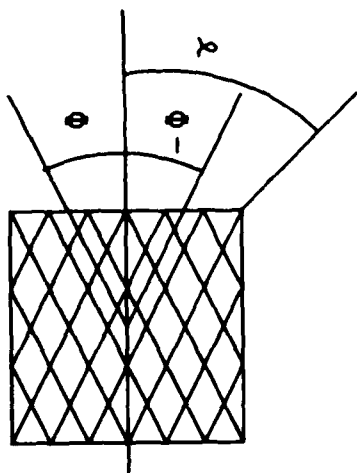


FIG.: 157



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 \times (1/9)
 Σ (0/1)

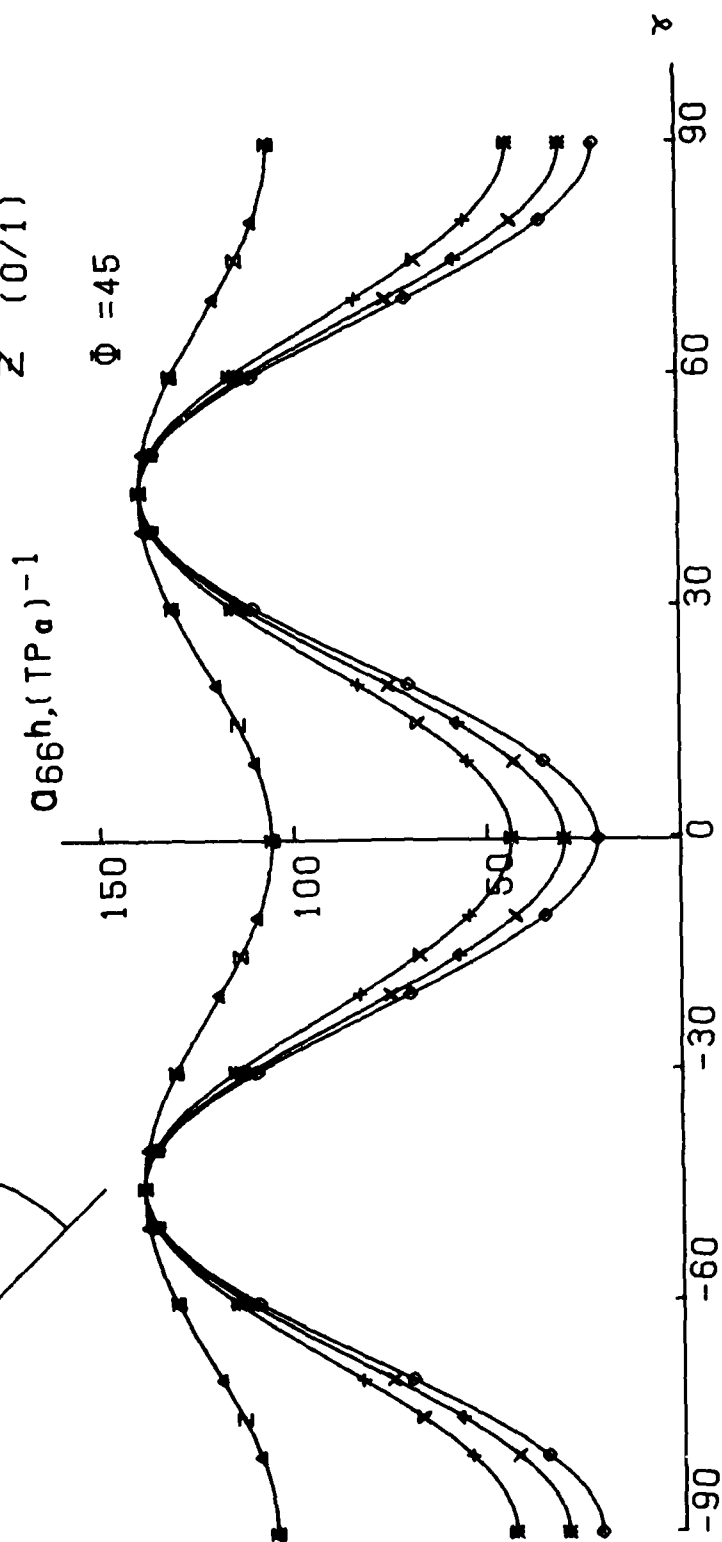


FIG.: 158

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 Σ (0/1)

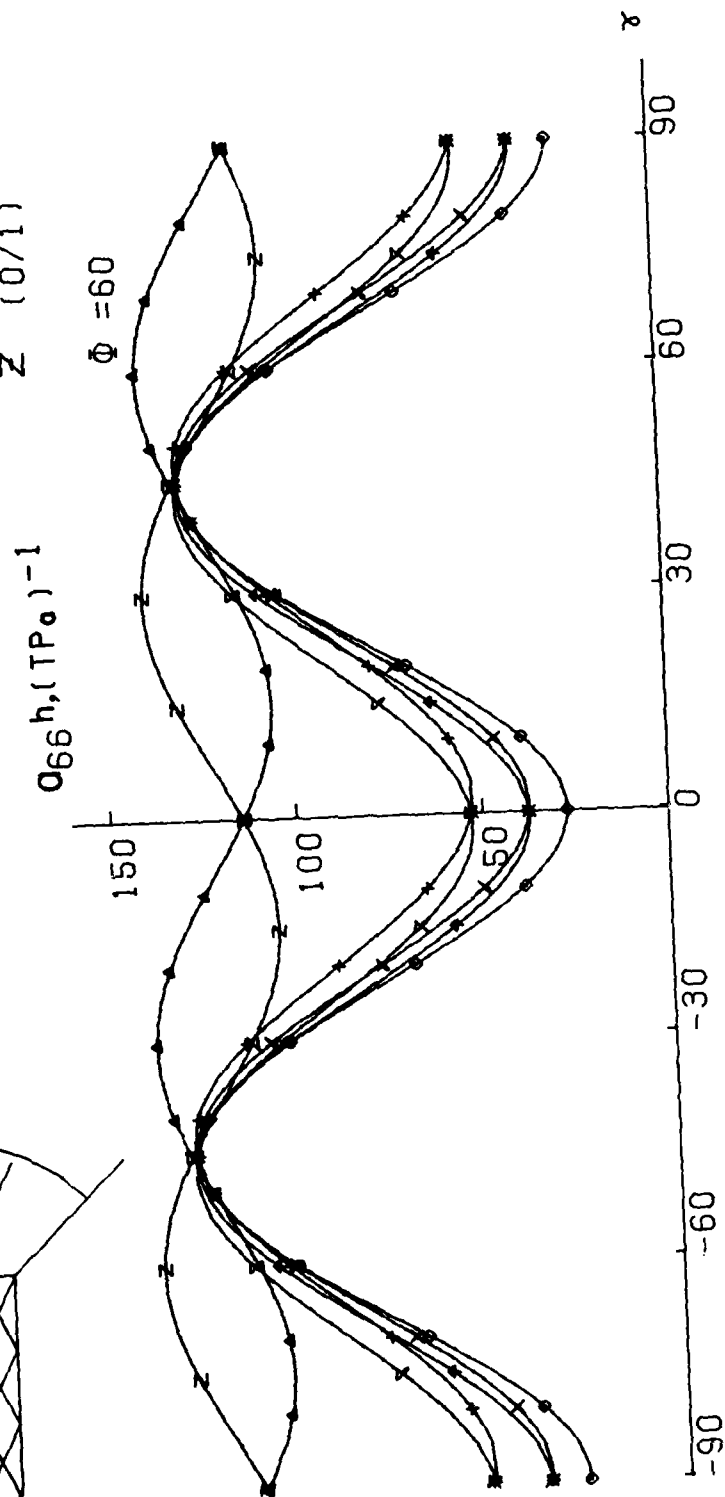
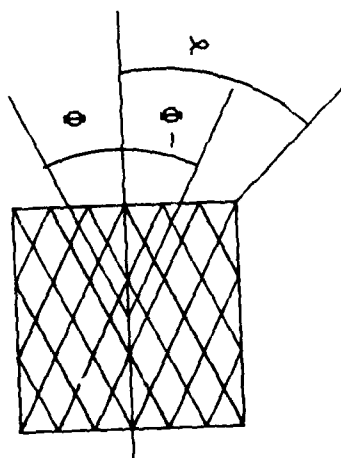


FIG.:159

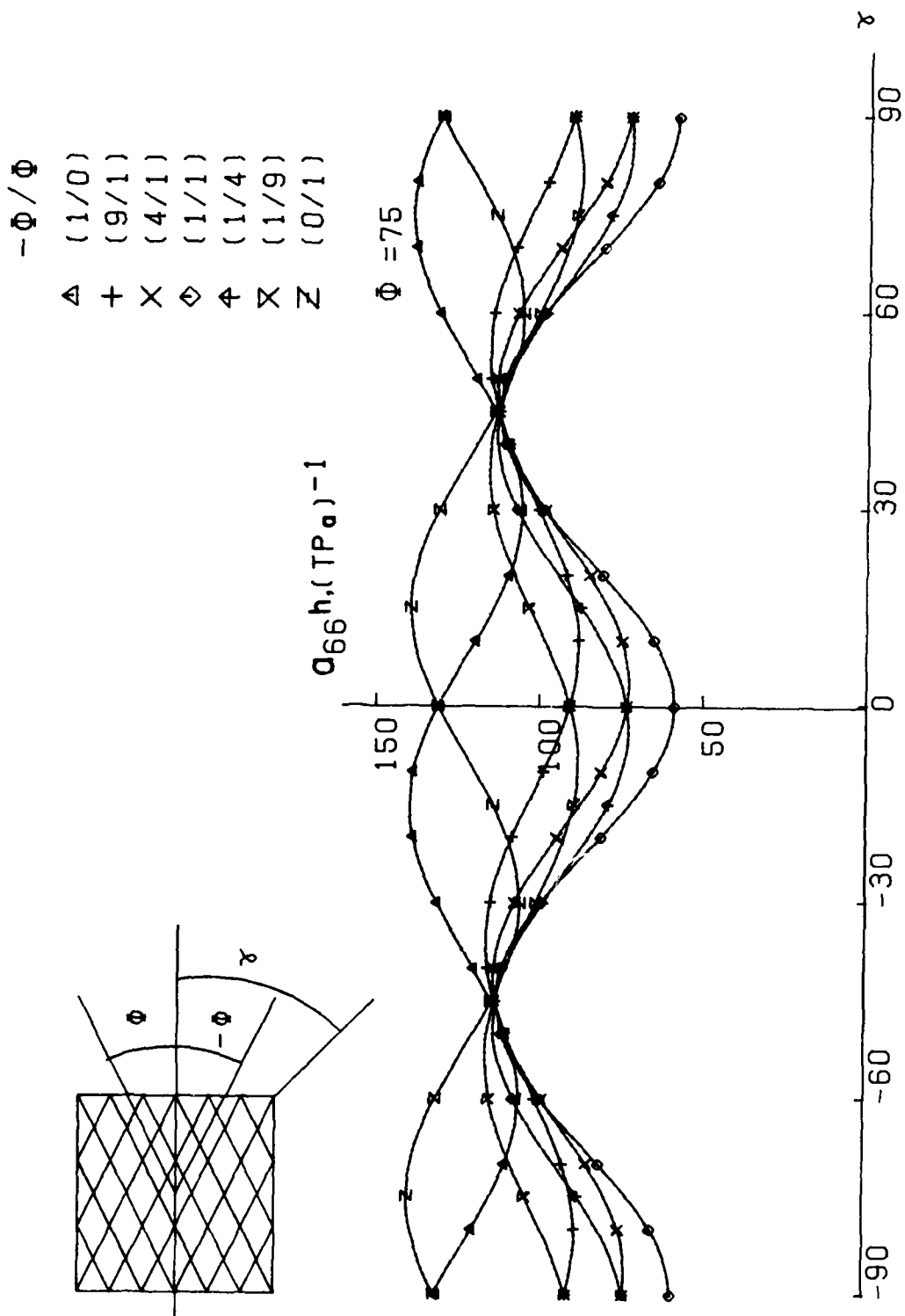
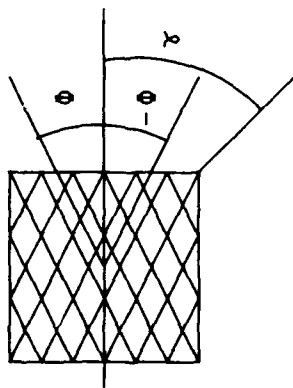


FIG.: 160



Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = -75$

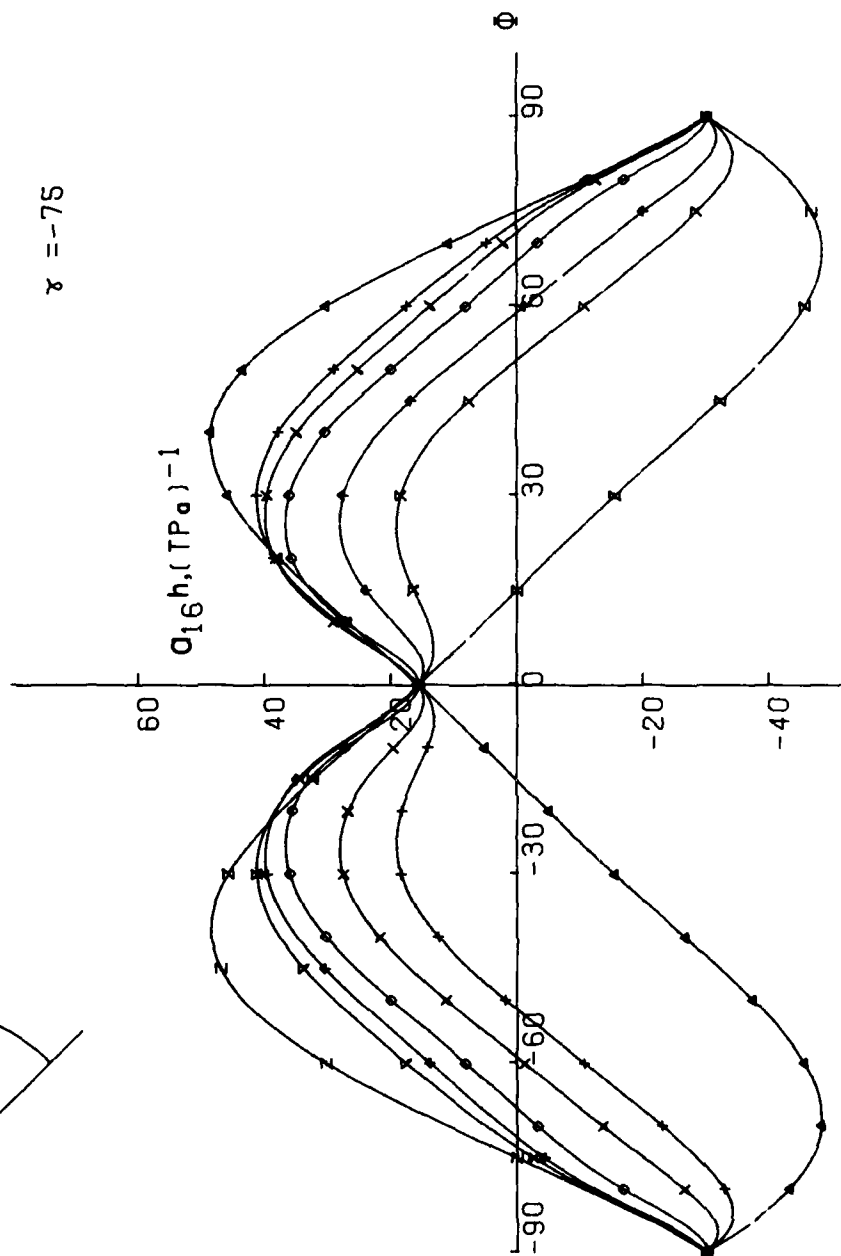
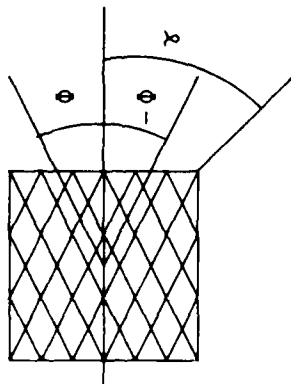


FIG.: 161



ϕ/Φ

Δ	$(1/0)$
$+$	$(9/1)$
\times	$(4/1)$
\diamond	$(1/1)$
\oplus	$(1/4)$
\otimes	$(1/9)$
Σ	$(0/1)$

$\chi = -60$

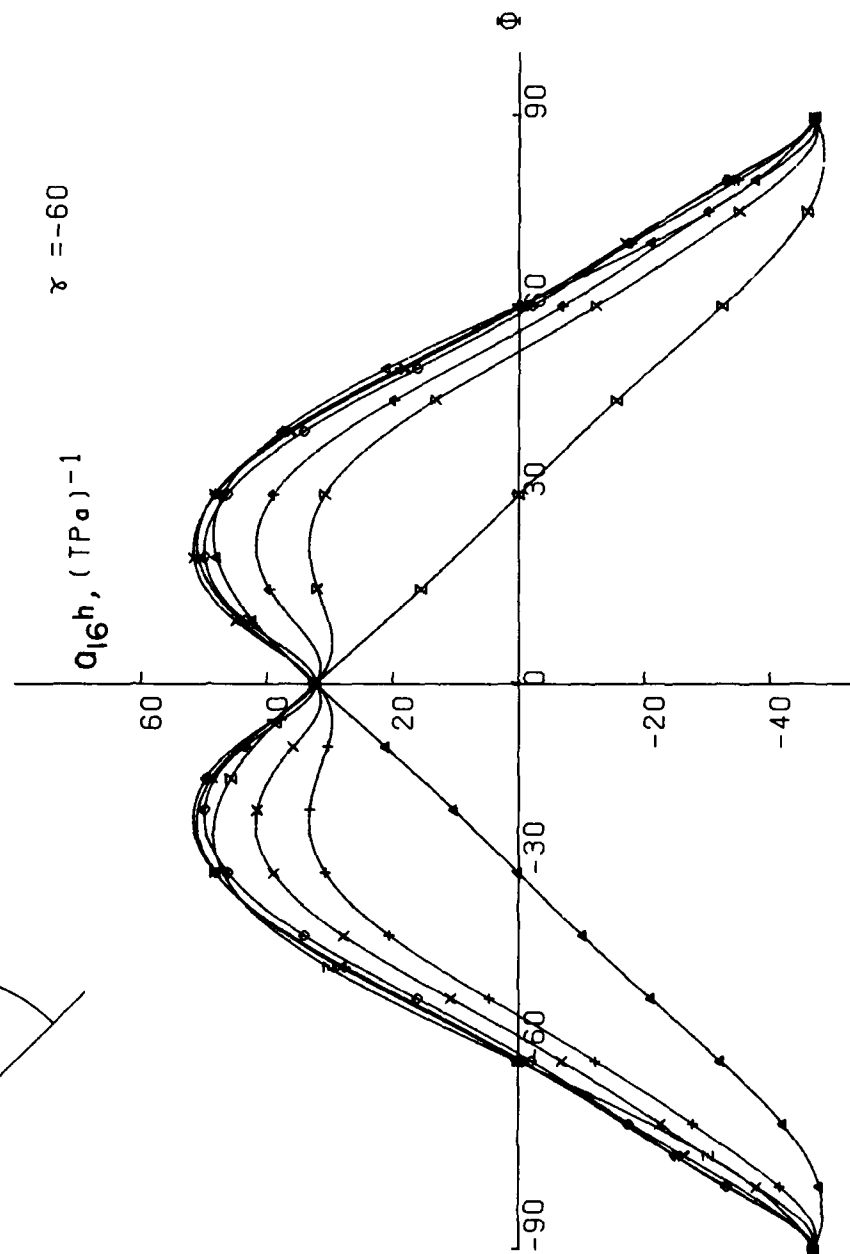
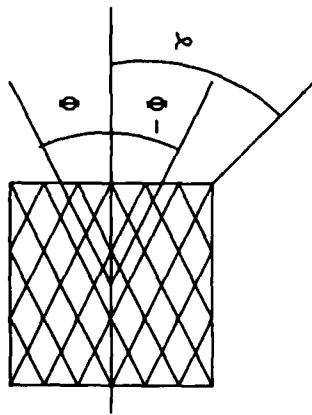


FIG.:162



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = -45$

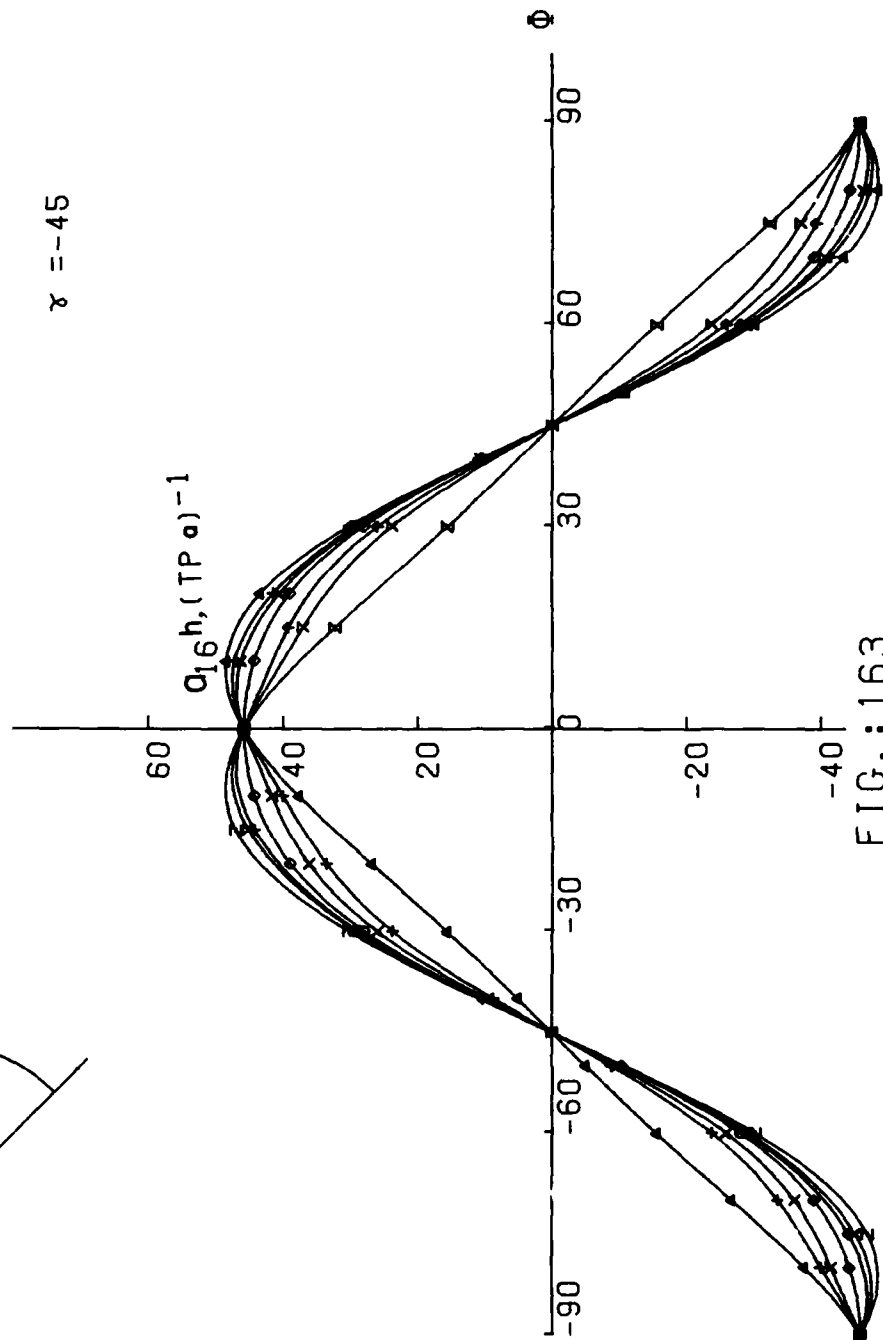


FIG.: 163

Φ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\chi = -30$

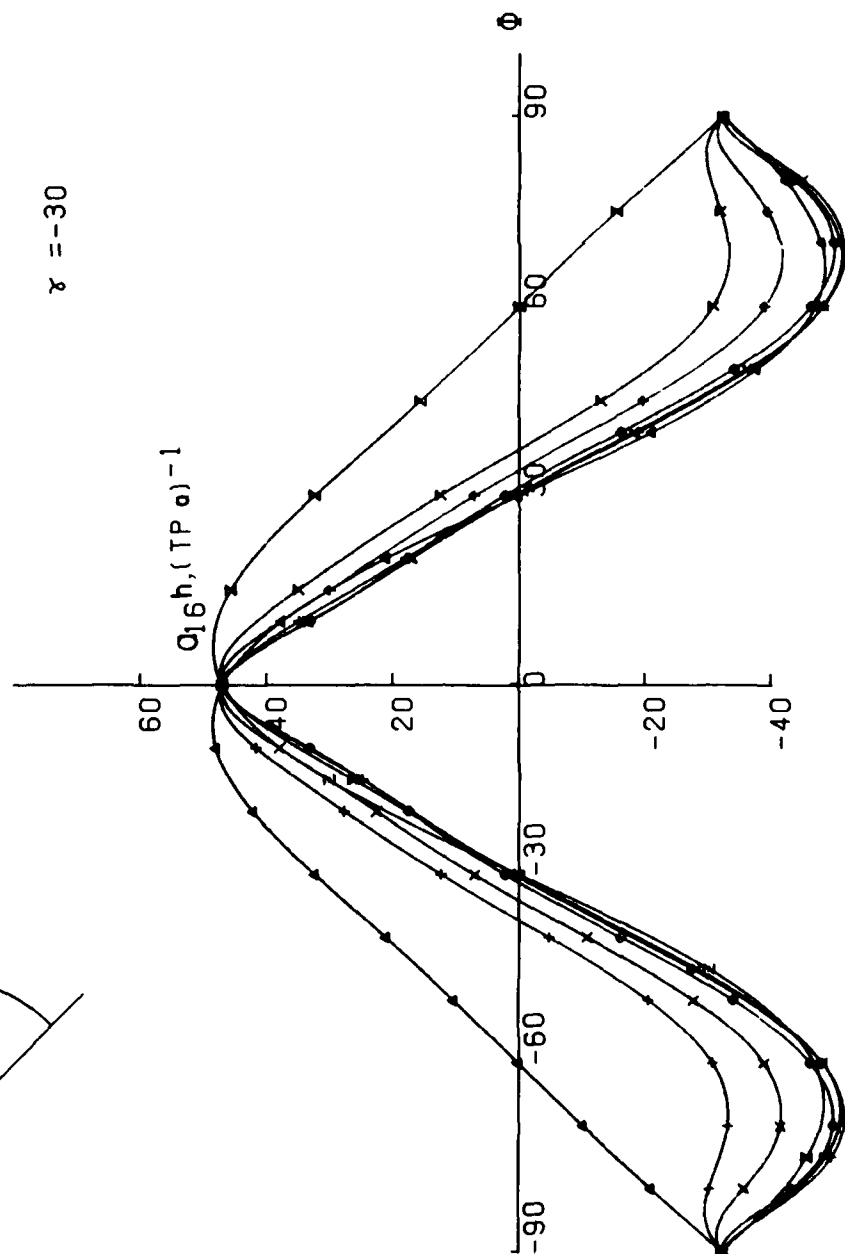
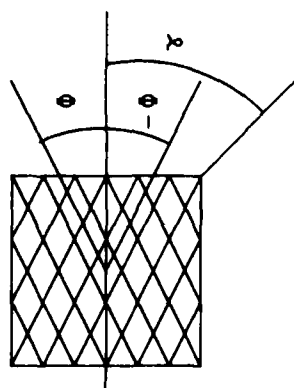
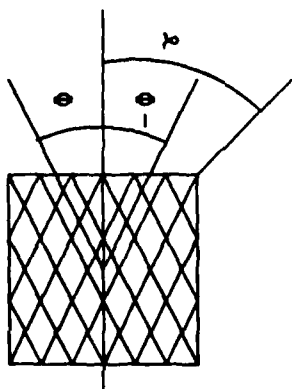


FIG.: 164



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)
 $\gamma = -15$

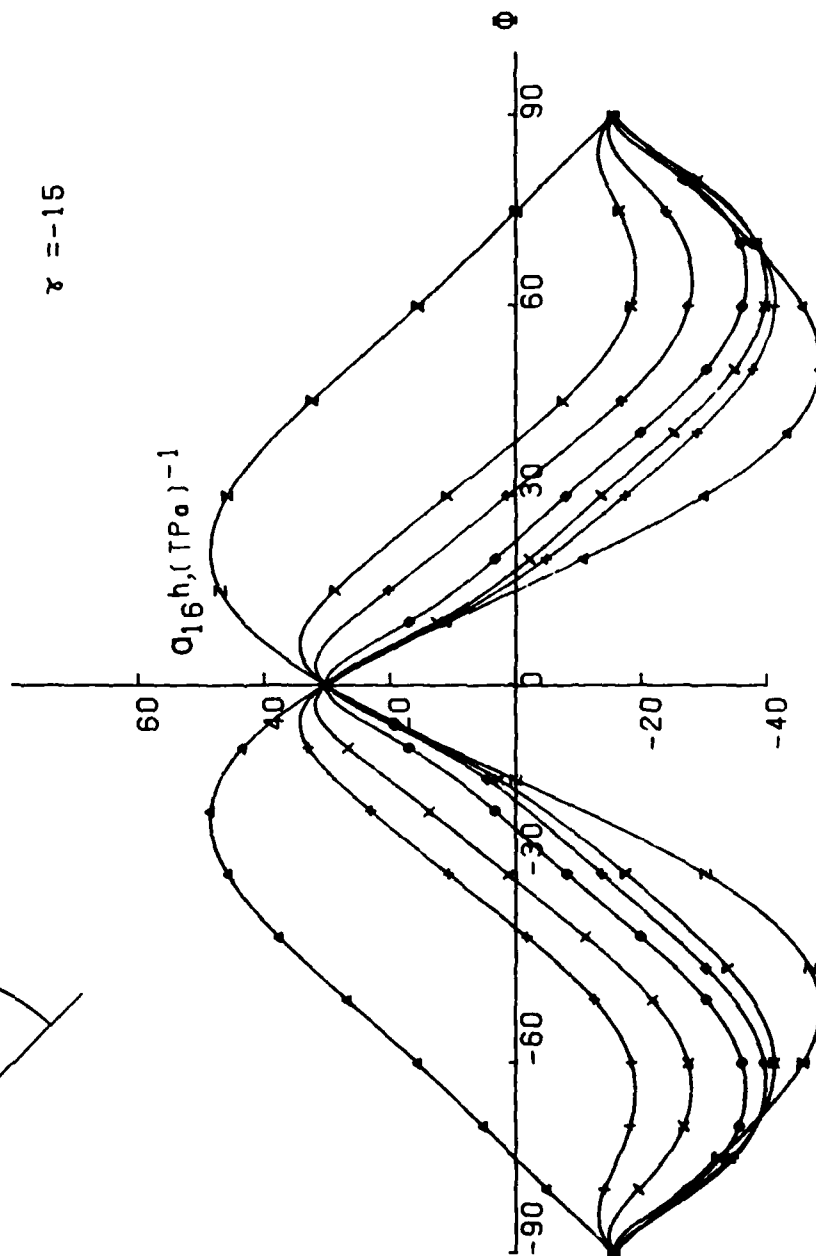
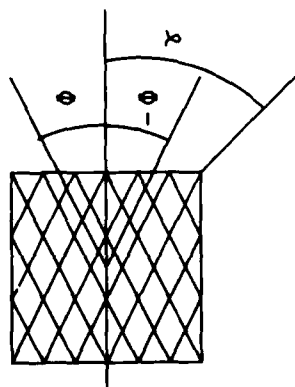


FIG.:165



Φ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)
 $\alpha = 0$

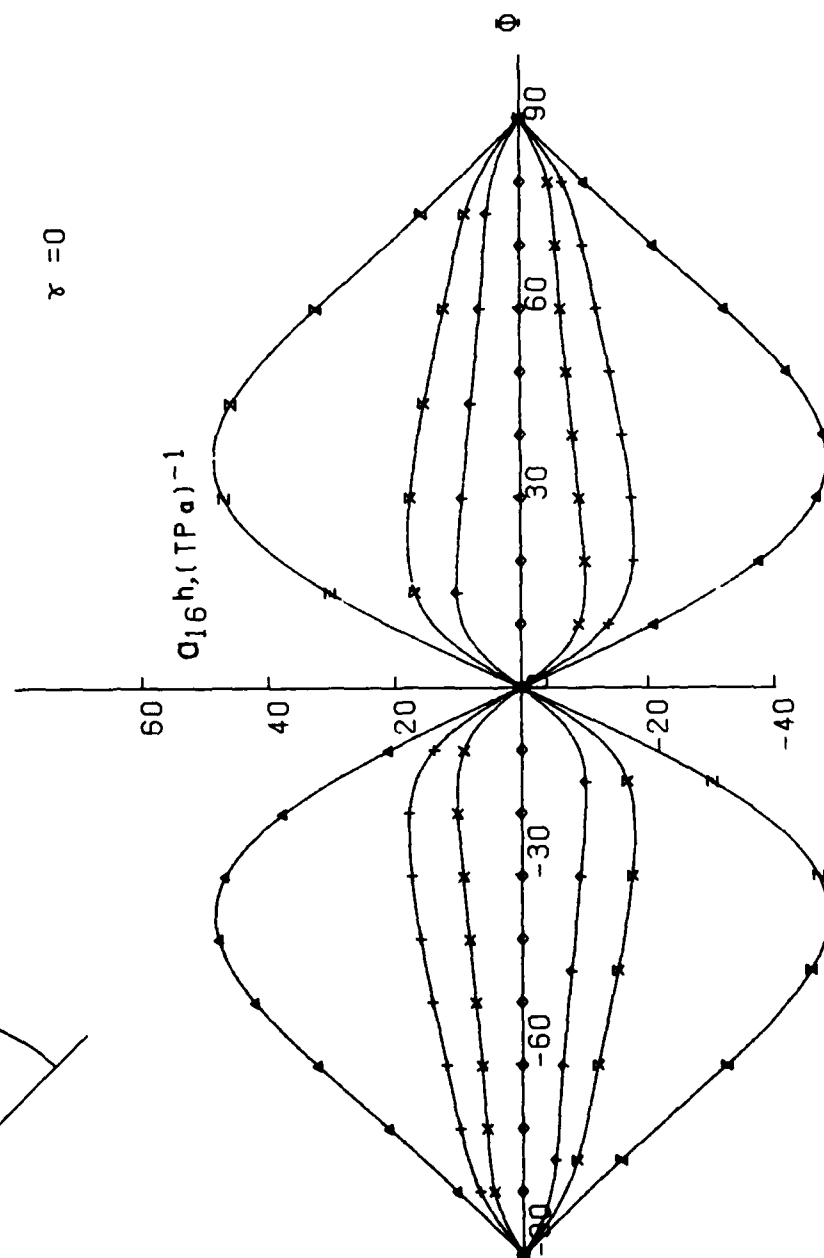
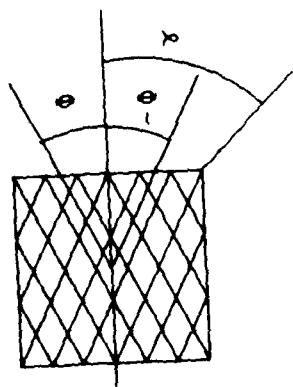


FIG.:166



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \blacktriangle (1/4)
 \times (1/9)
 Z (0/1)
 $\chi = 15$

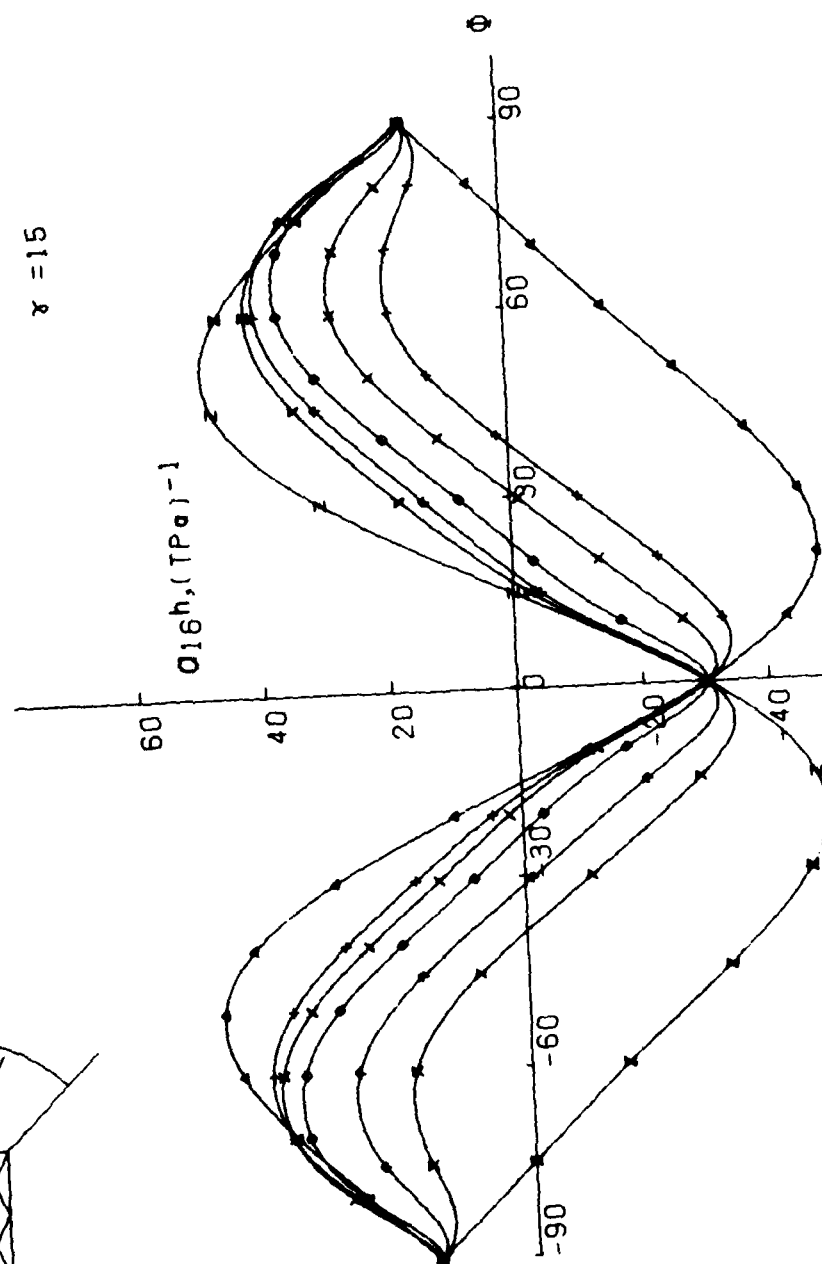


FIG.:167

Φ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \clubsuit (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = 30$

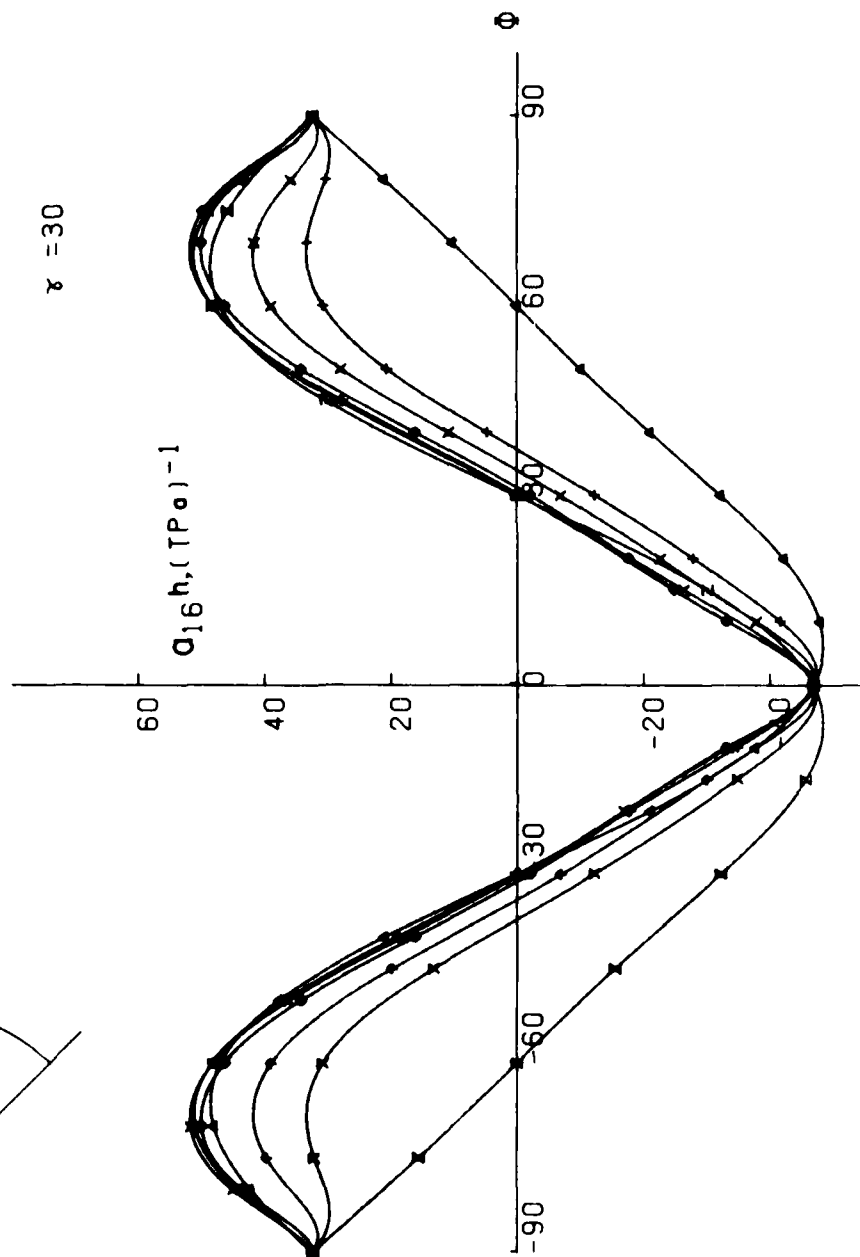
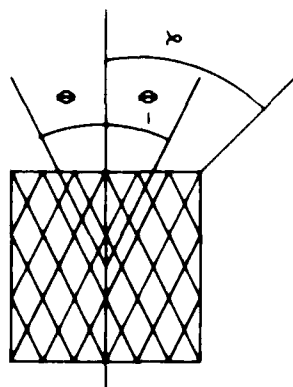
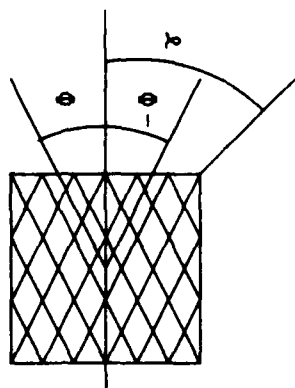


FIG.:168



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = 45$

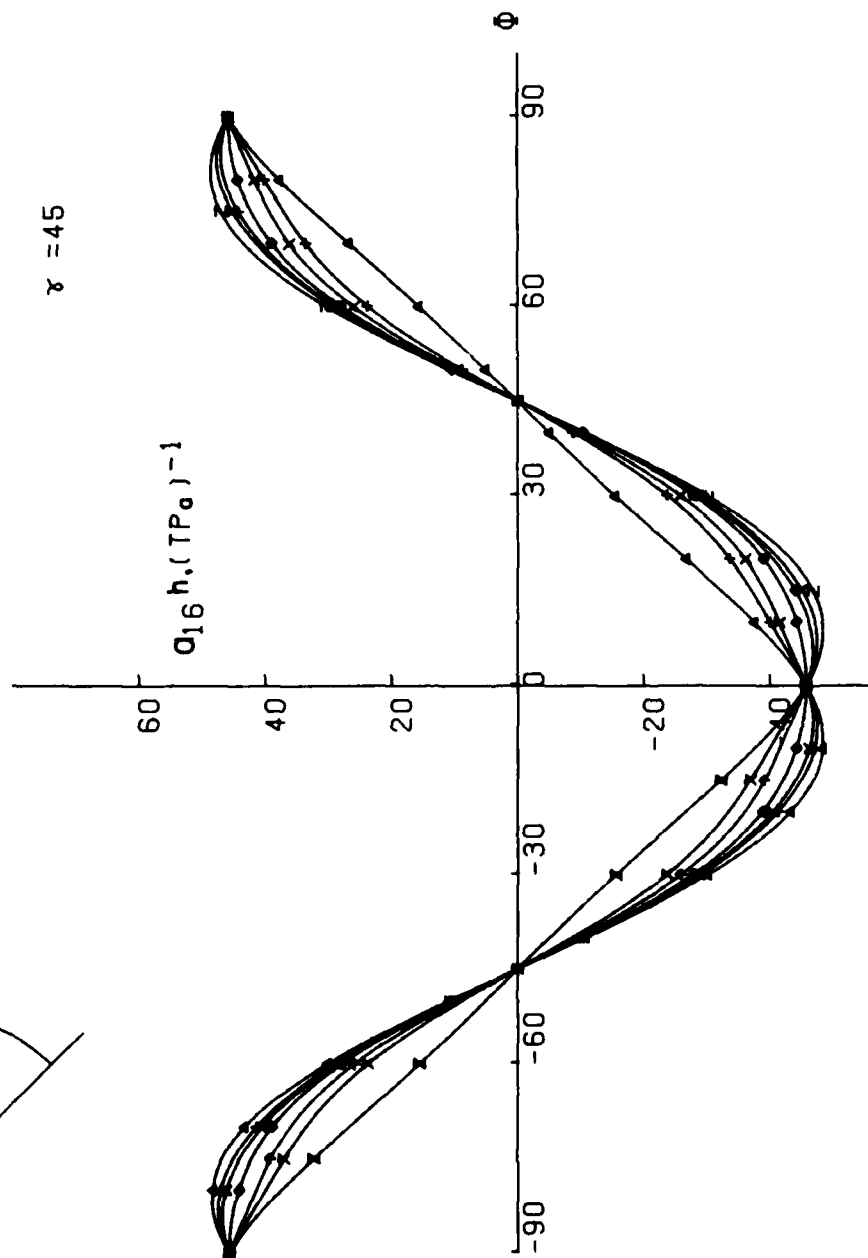
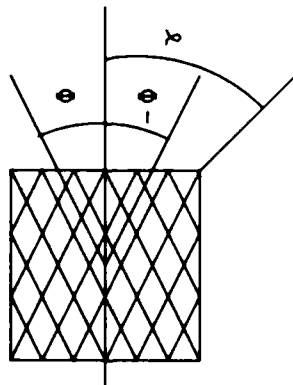


FIG.: 169



Φ/Φ

Δ	(1/0)
+	(9/1)
X	(4/1)
\diamond	(1/1)
\blacklozenge	(1/4)
X	(1/9)
Z	(0/1)

$\gamma = 60$

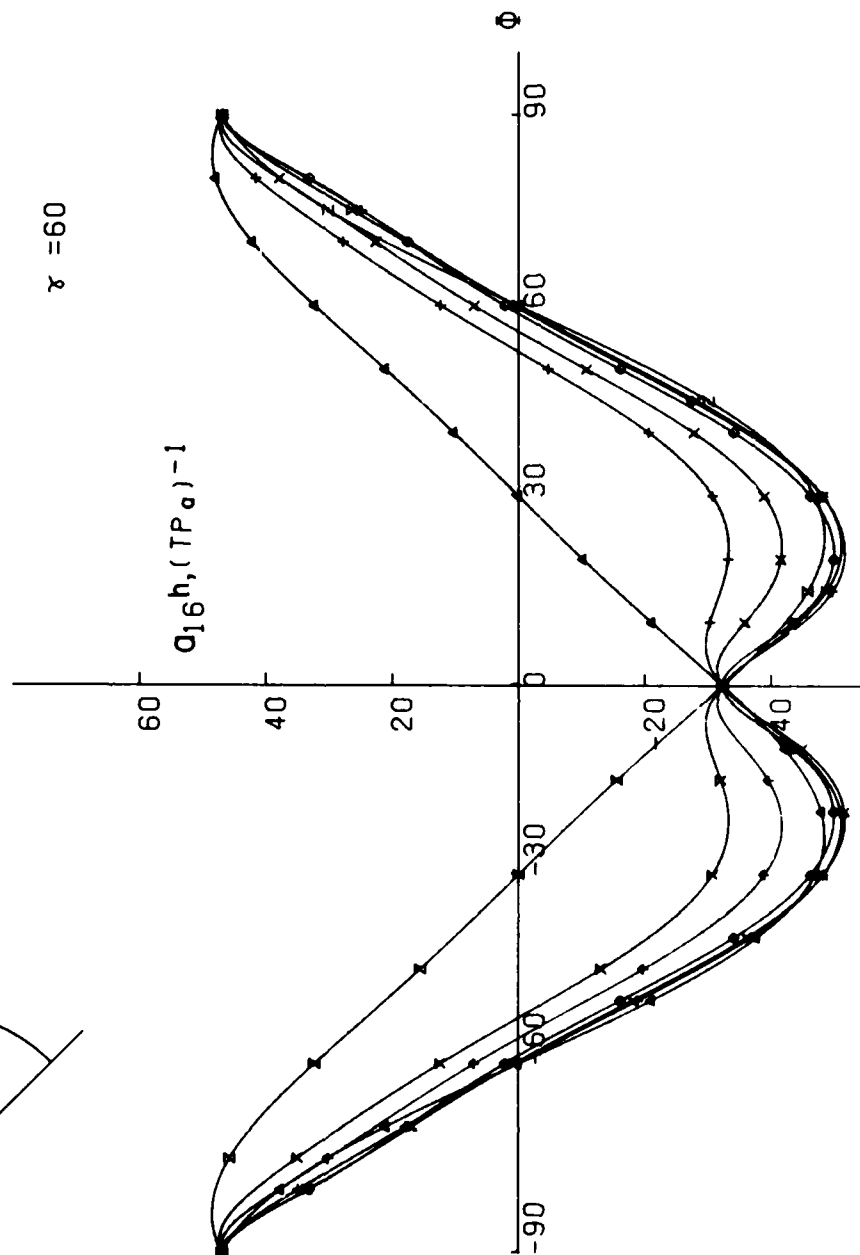


FIG.:170

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \blacktriangle (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = 75$

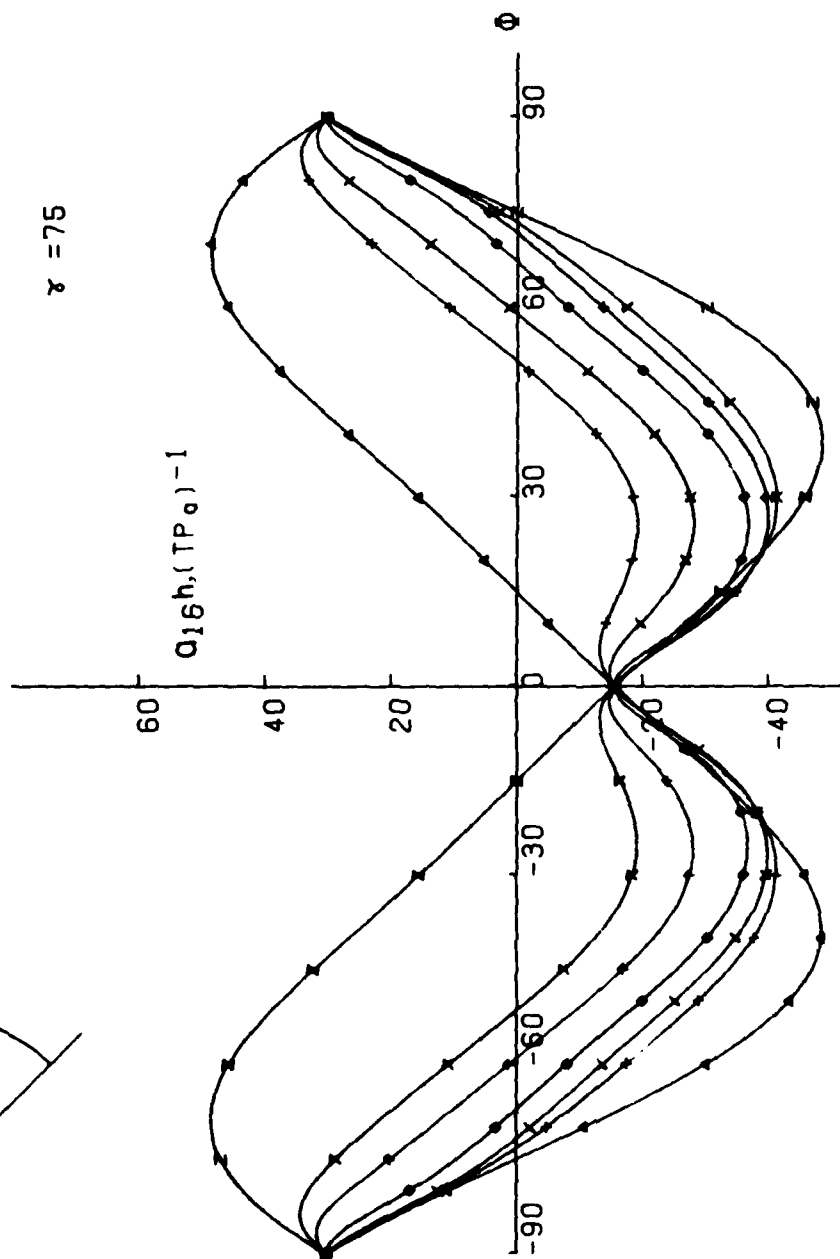
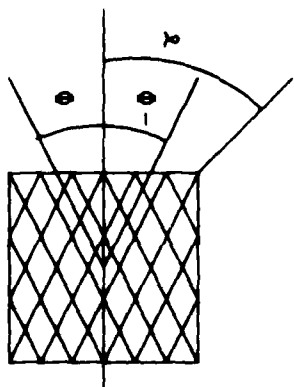
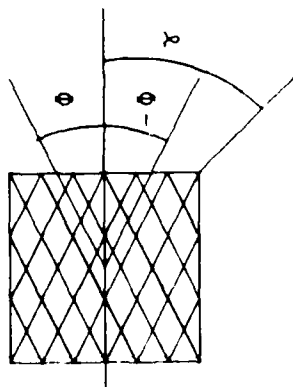


FIG.:171



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Z (0/1)
 $\phi = 15$

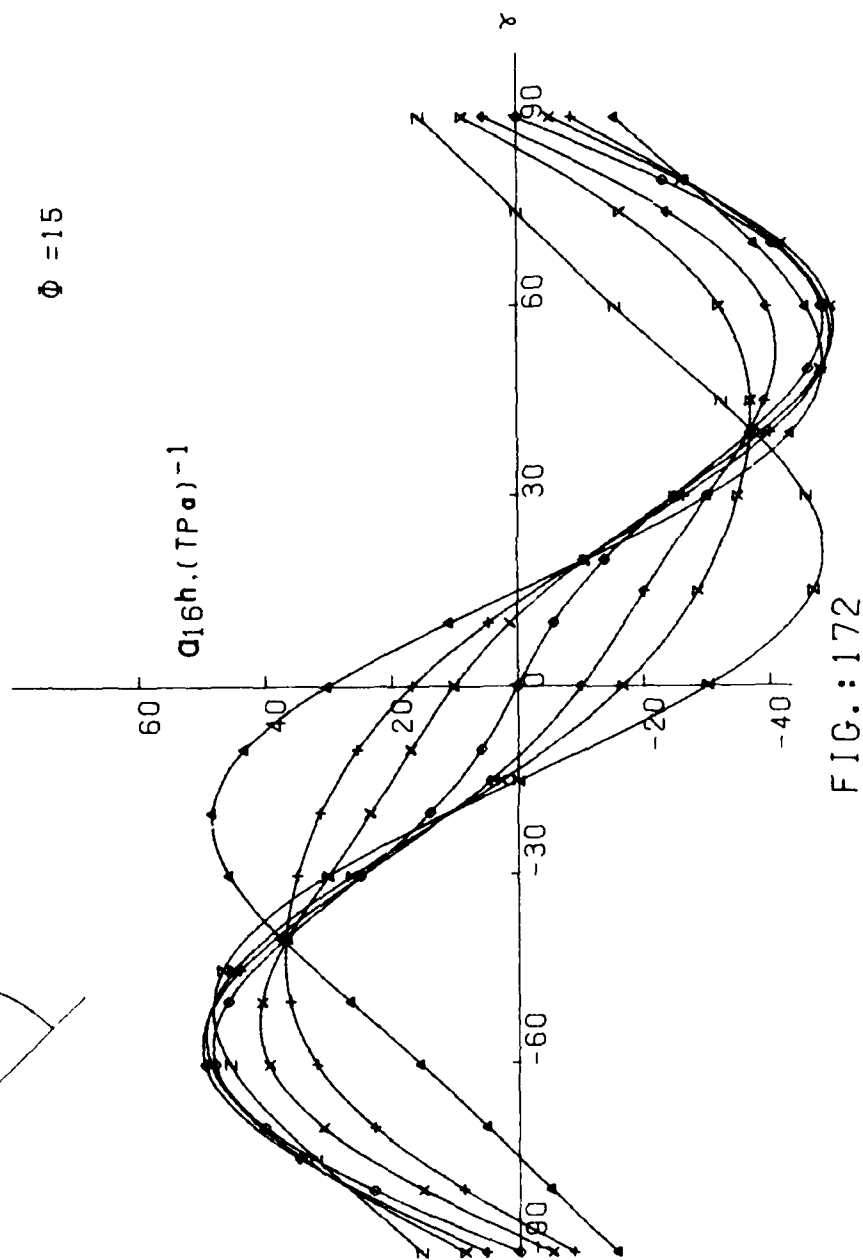


FIG.:172

$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 Σ (1/9)
 Z (0/1)

$\phi = 30$

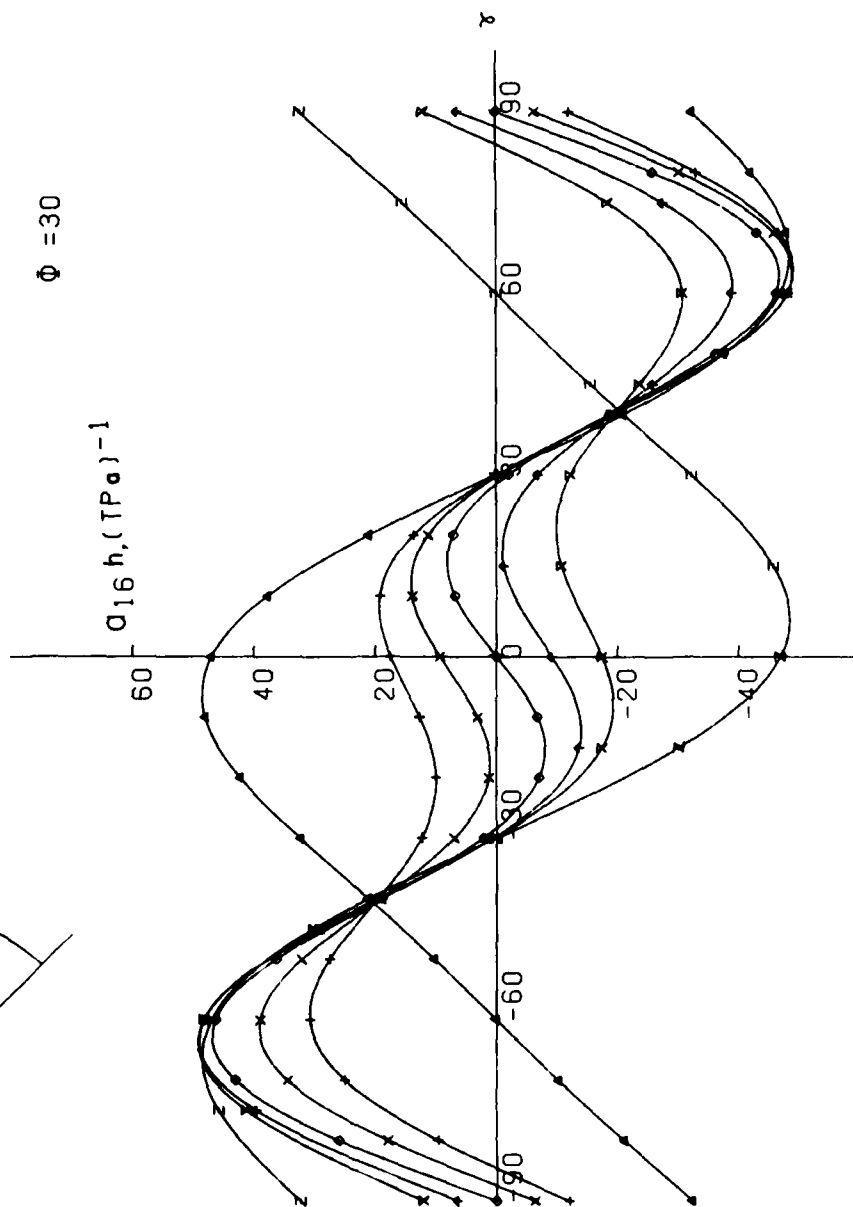
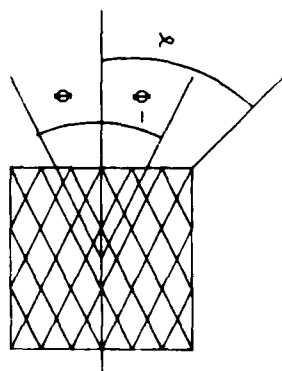
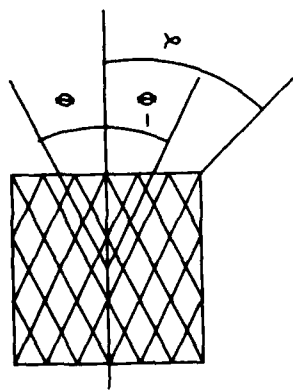


FIG.:173



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 ∇ (0/1)

$\phi = 45$

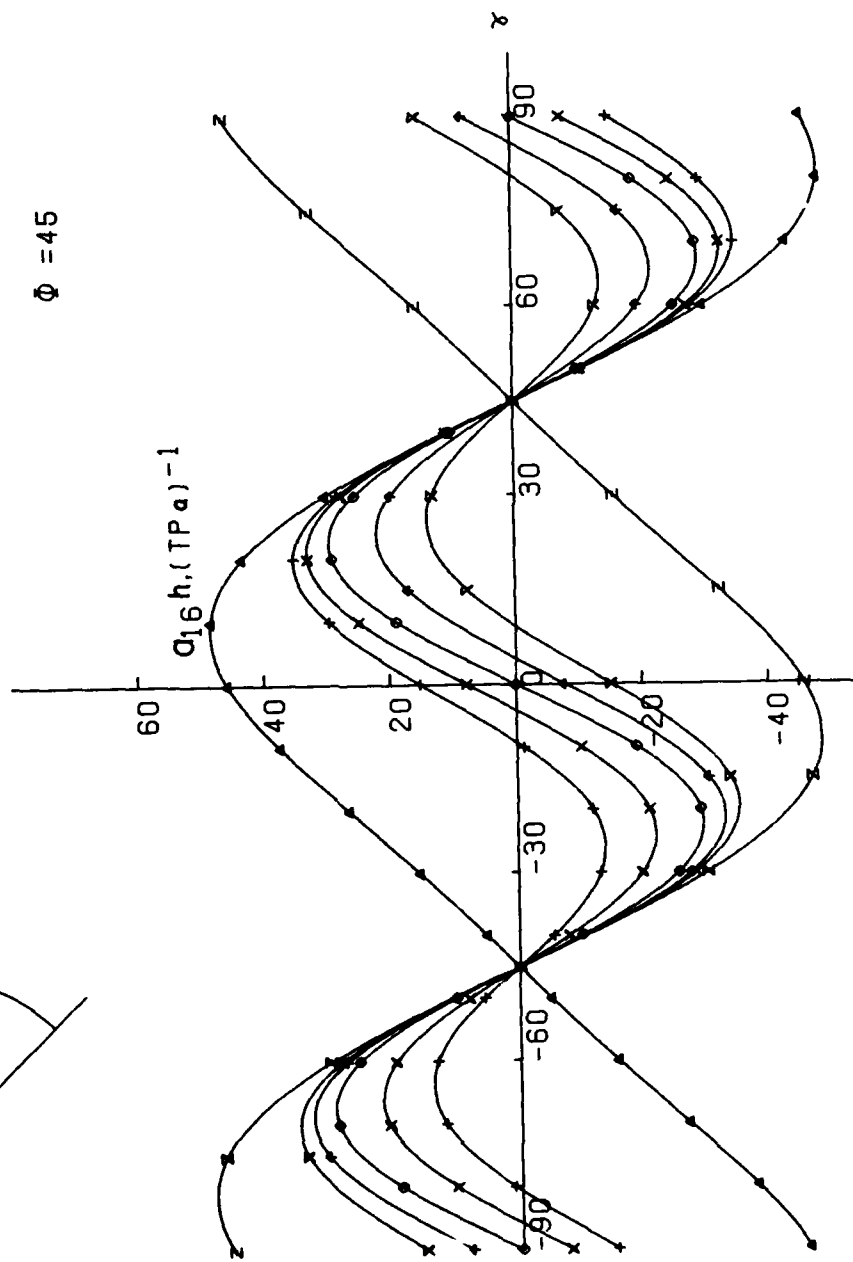
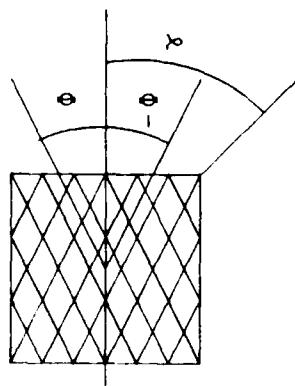


FIG.:174



$-\phi/\phi$

Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\phi = 60$

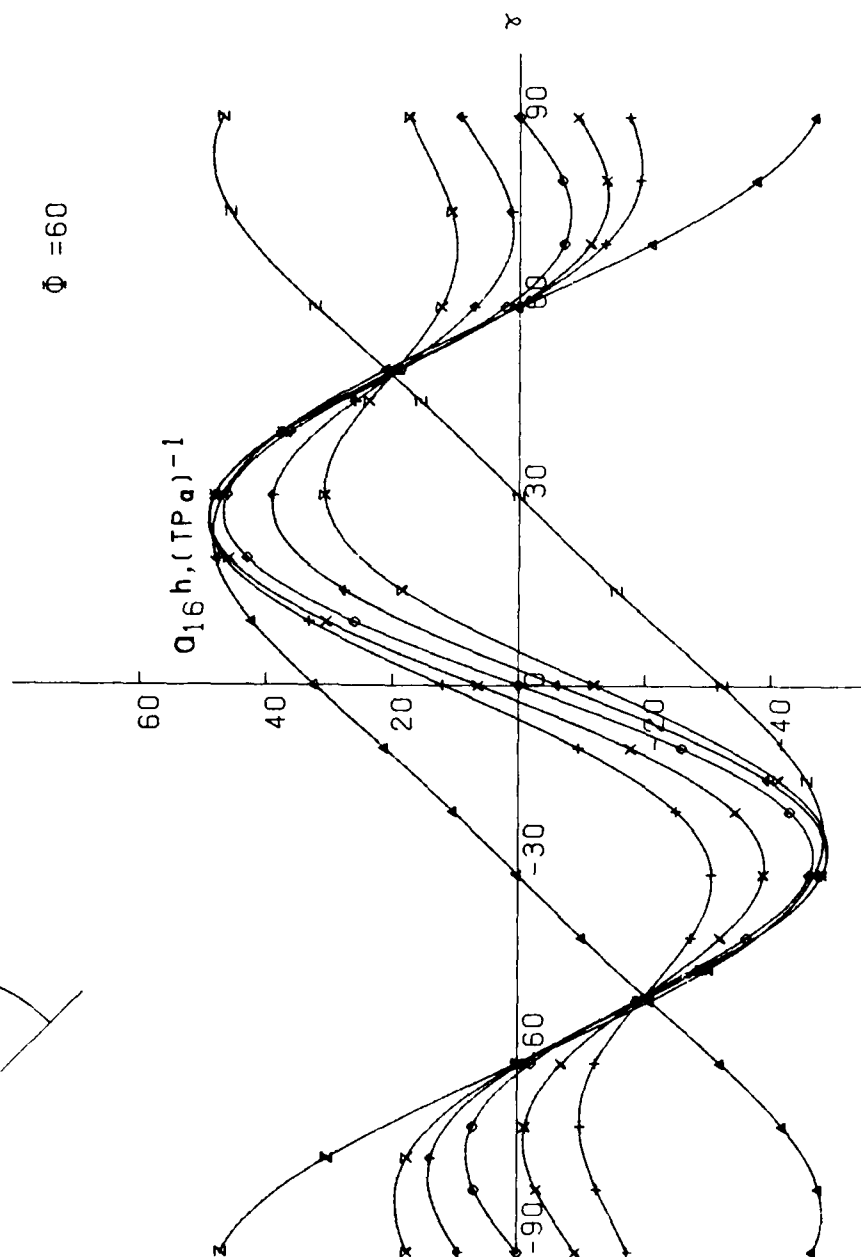
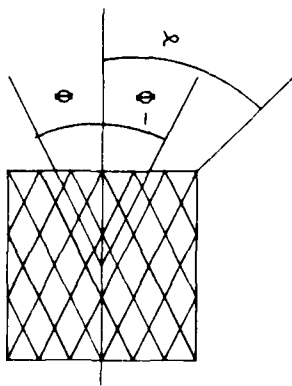


FIG.:175



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\phi = 75$

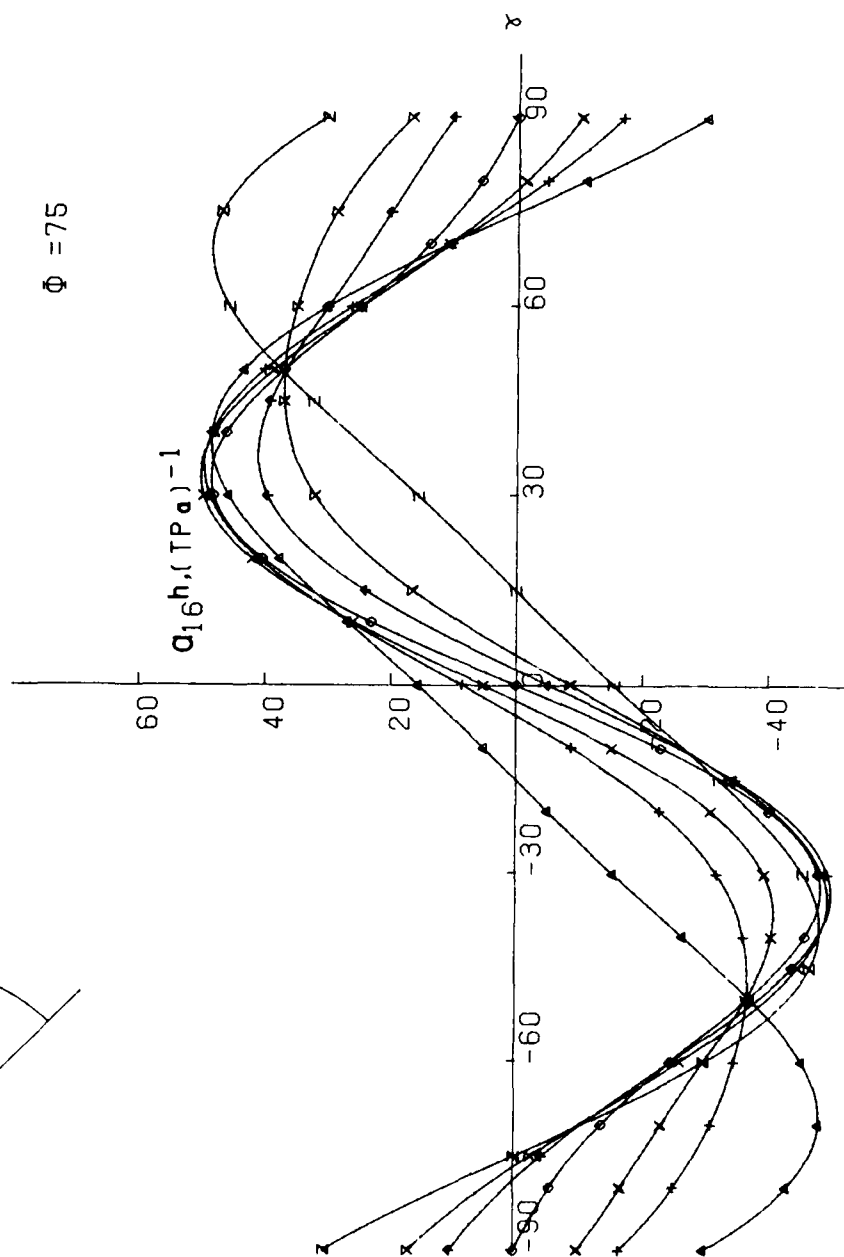
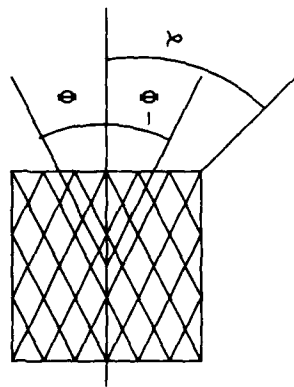


FIG.:176



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = -75$

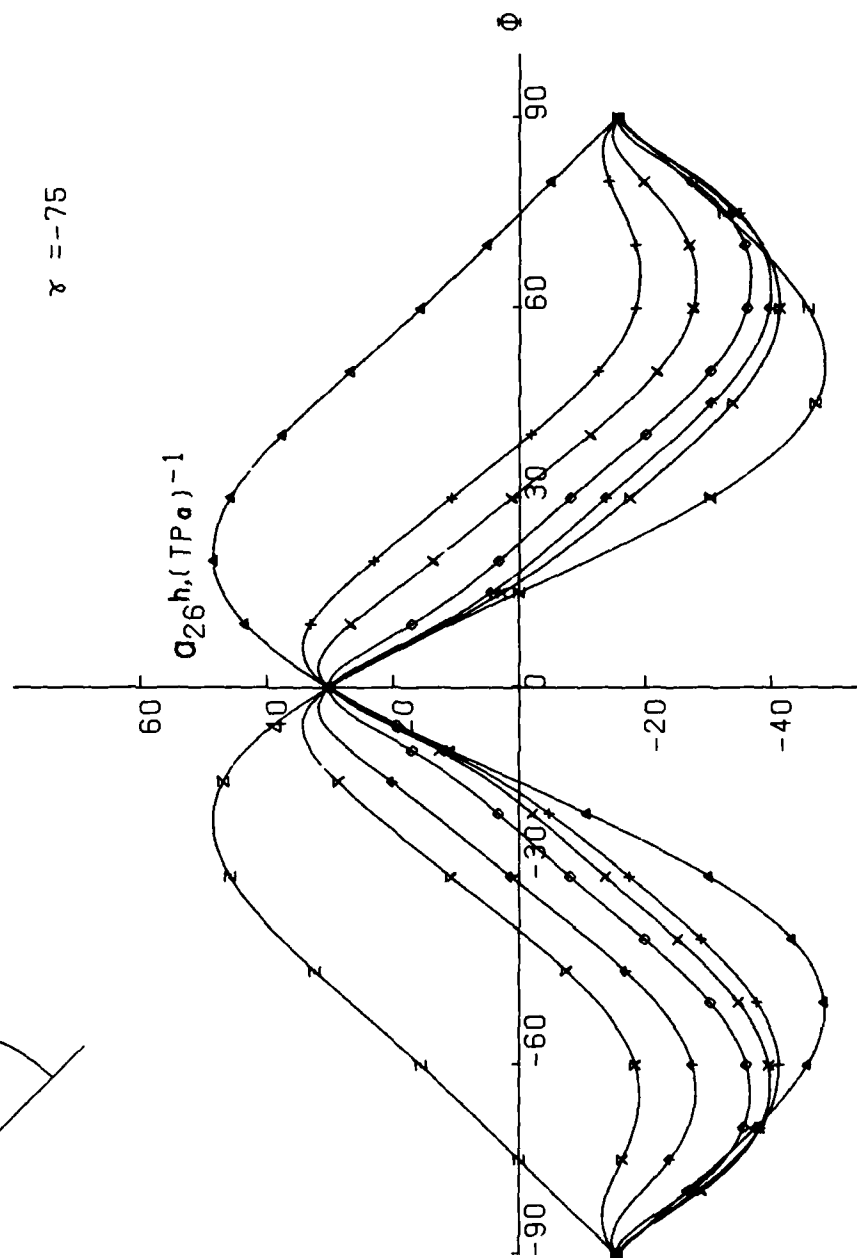


FIG.:177

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \times (1/9)
 Σ (0/1)

$\chi = -60$

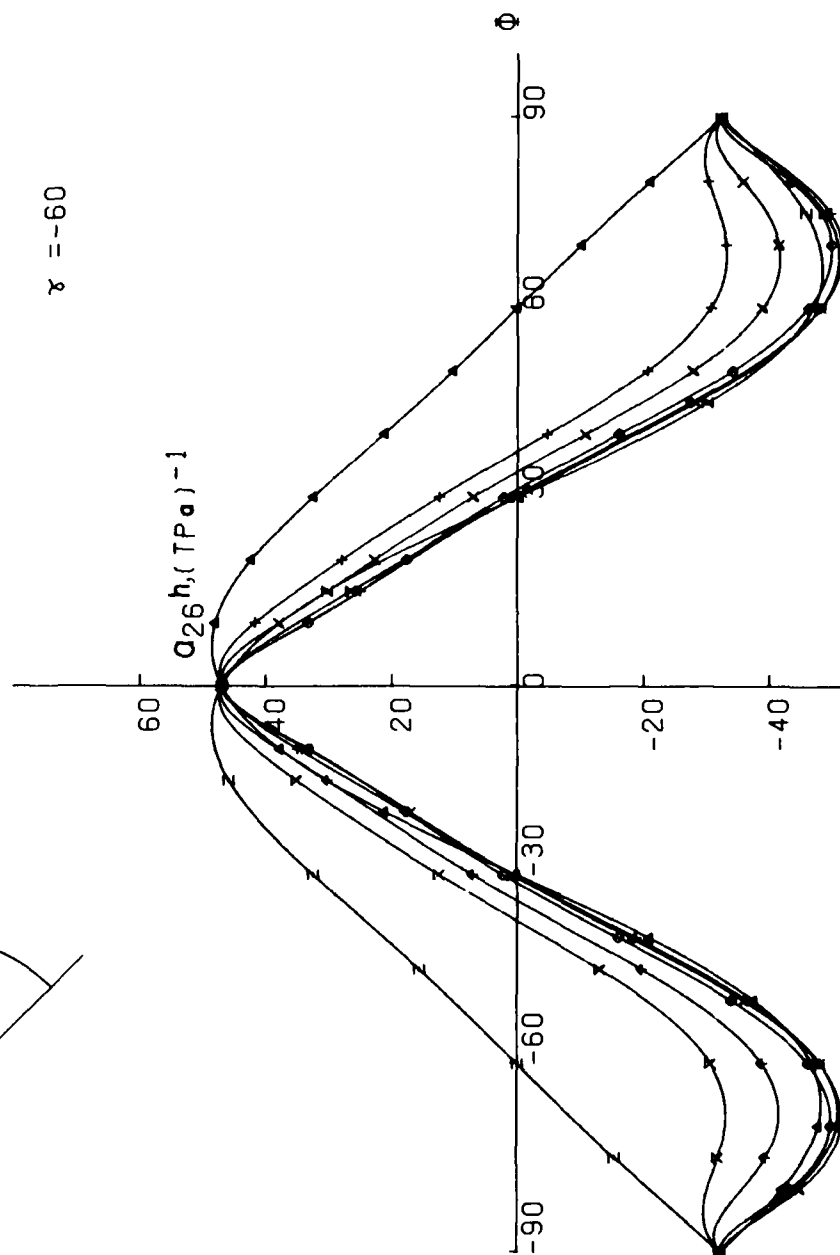
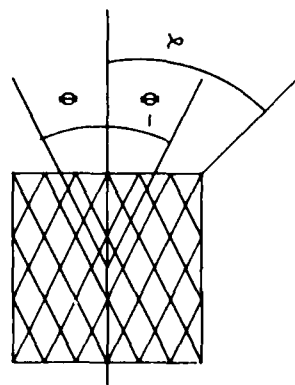
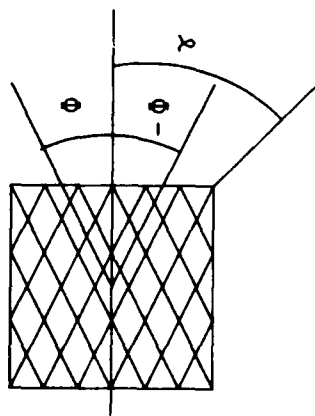


FIG.:178



Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \bowtie (1/9)
 Σ (0/1)

$\gamma = -45$

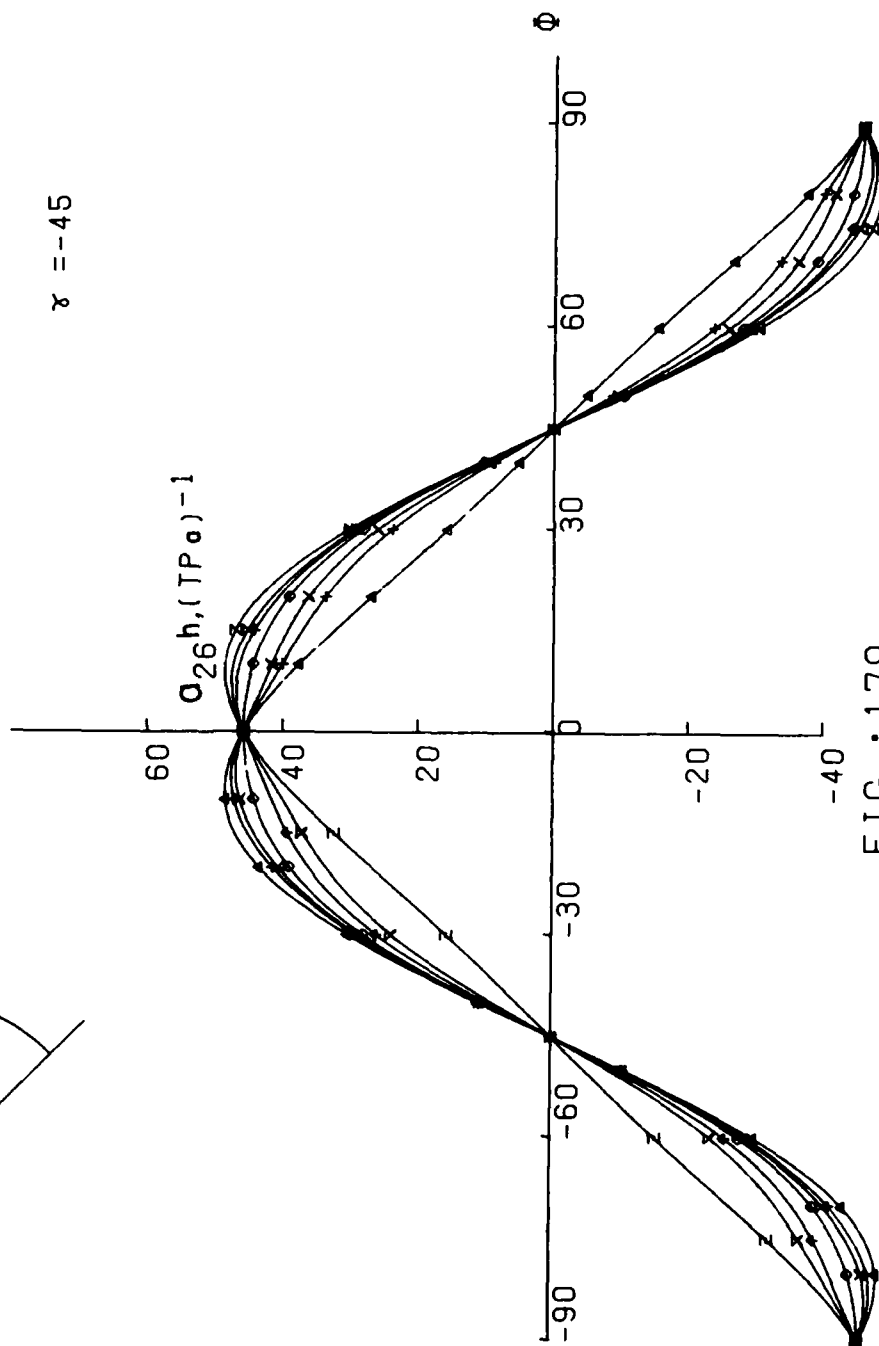
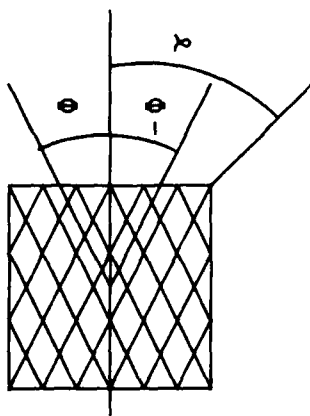


FIG.: 179



ϕ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\chi = -30$

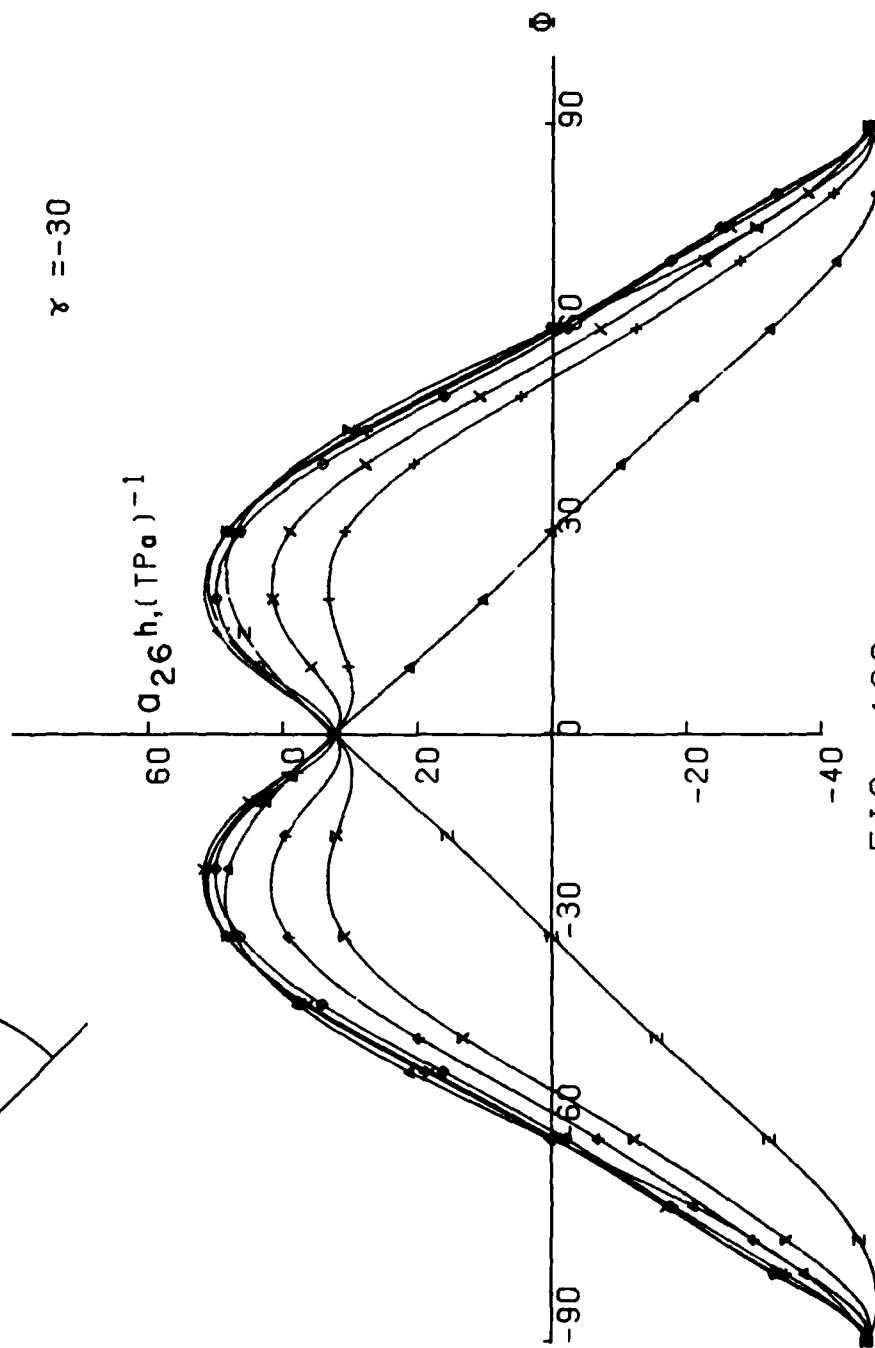
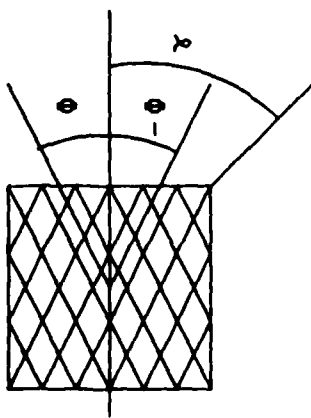


FIG.:180



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \clubsuit (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = -15$

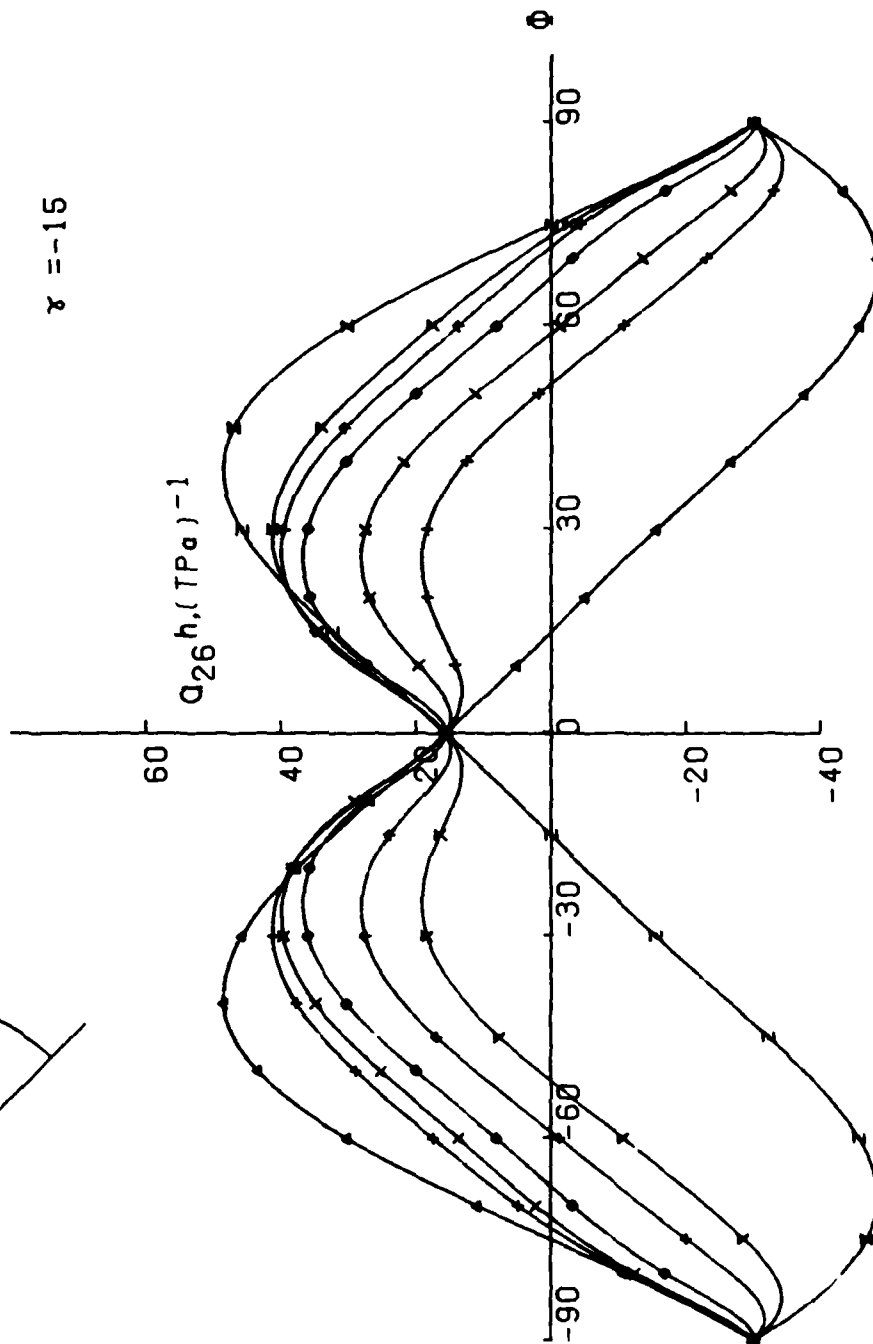


FIG.:181

Φ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = 0$

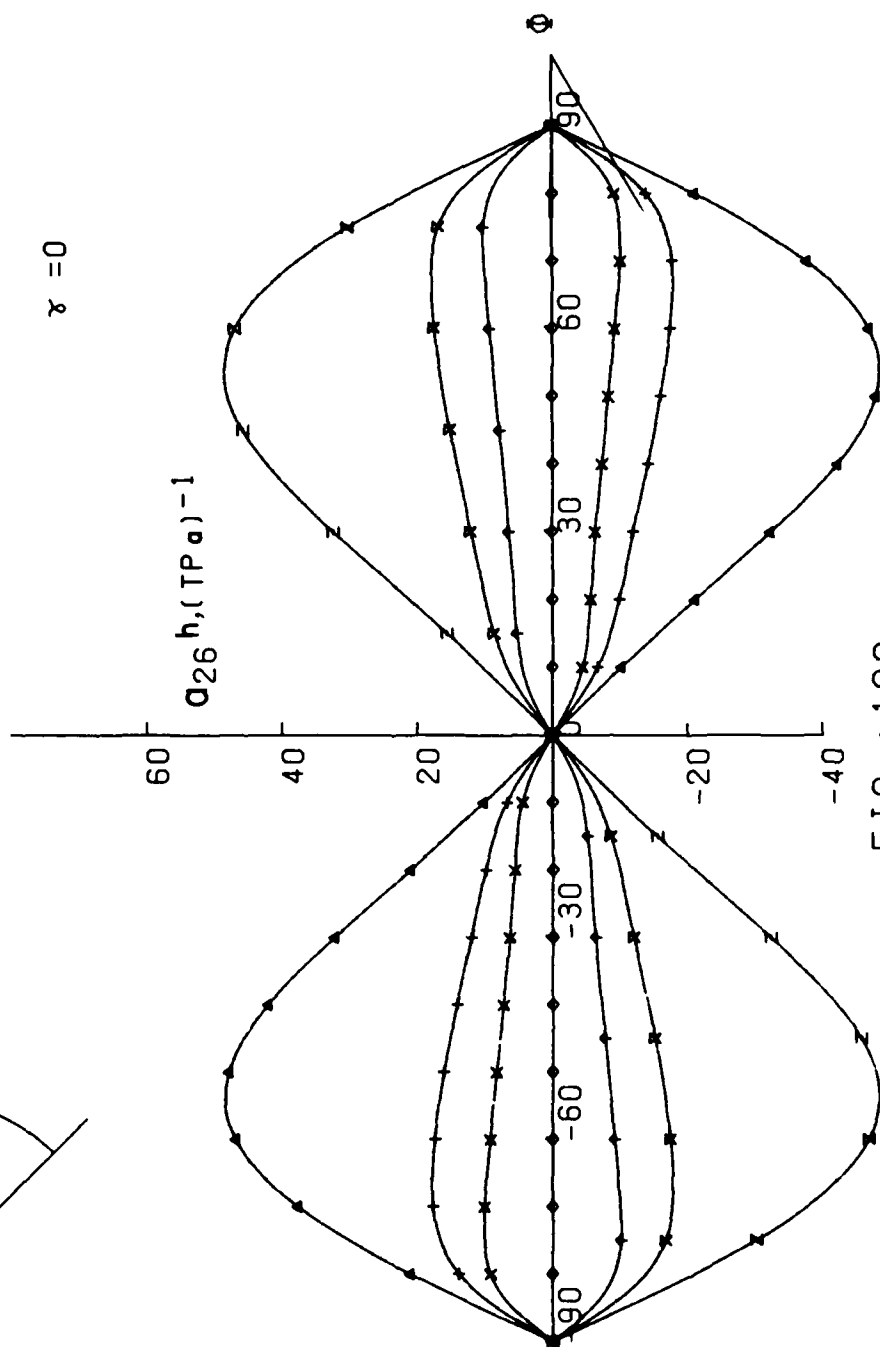
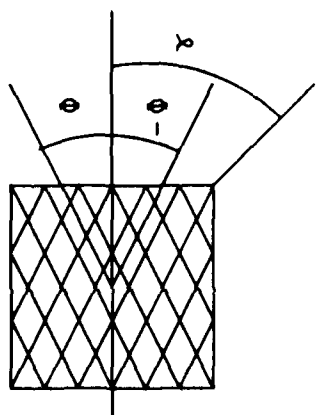
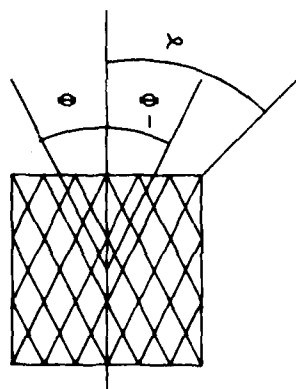


FIG.:182



Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Z (0/1)

$\chi = 15$

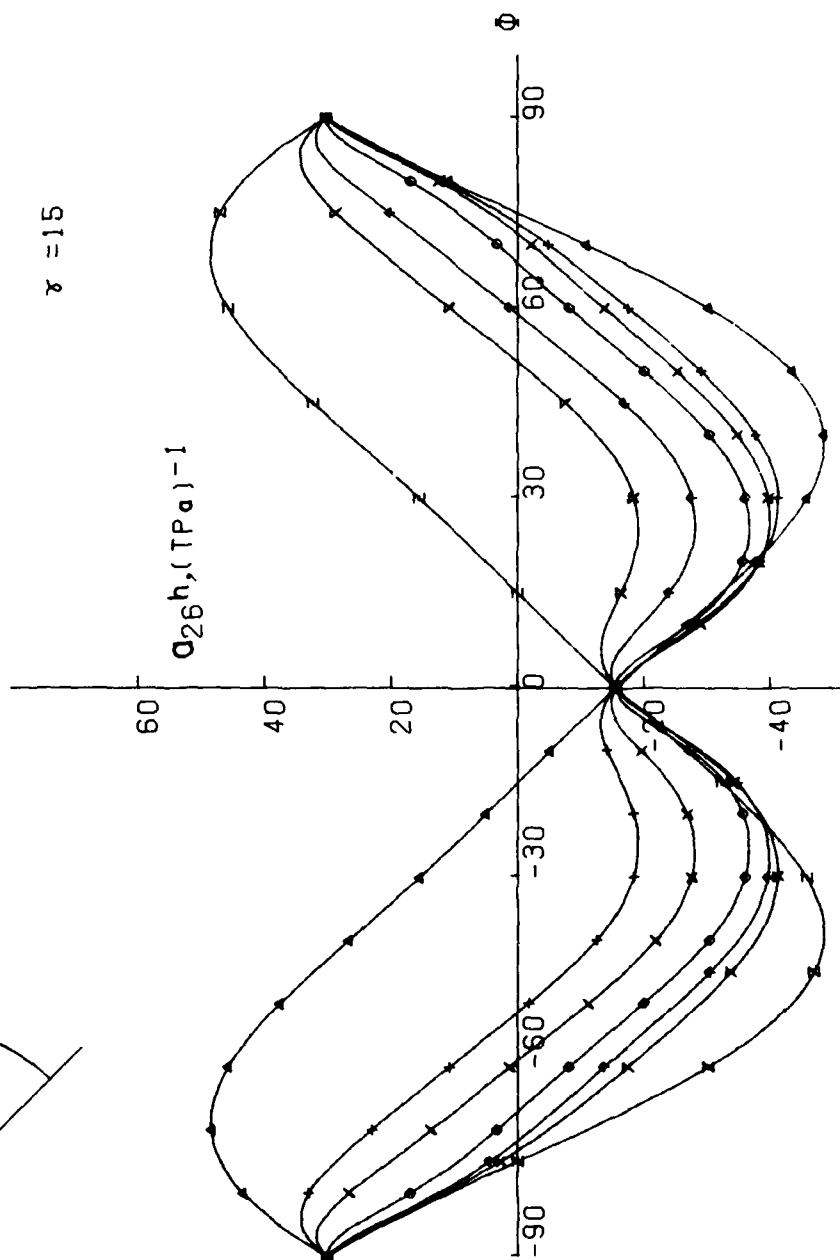
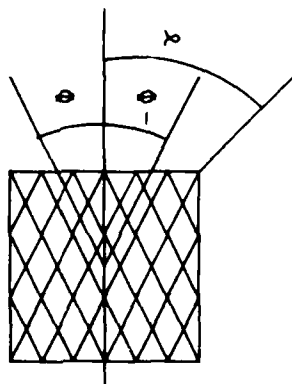


FIG.:183



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\chi = 30$

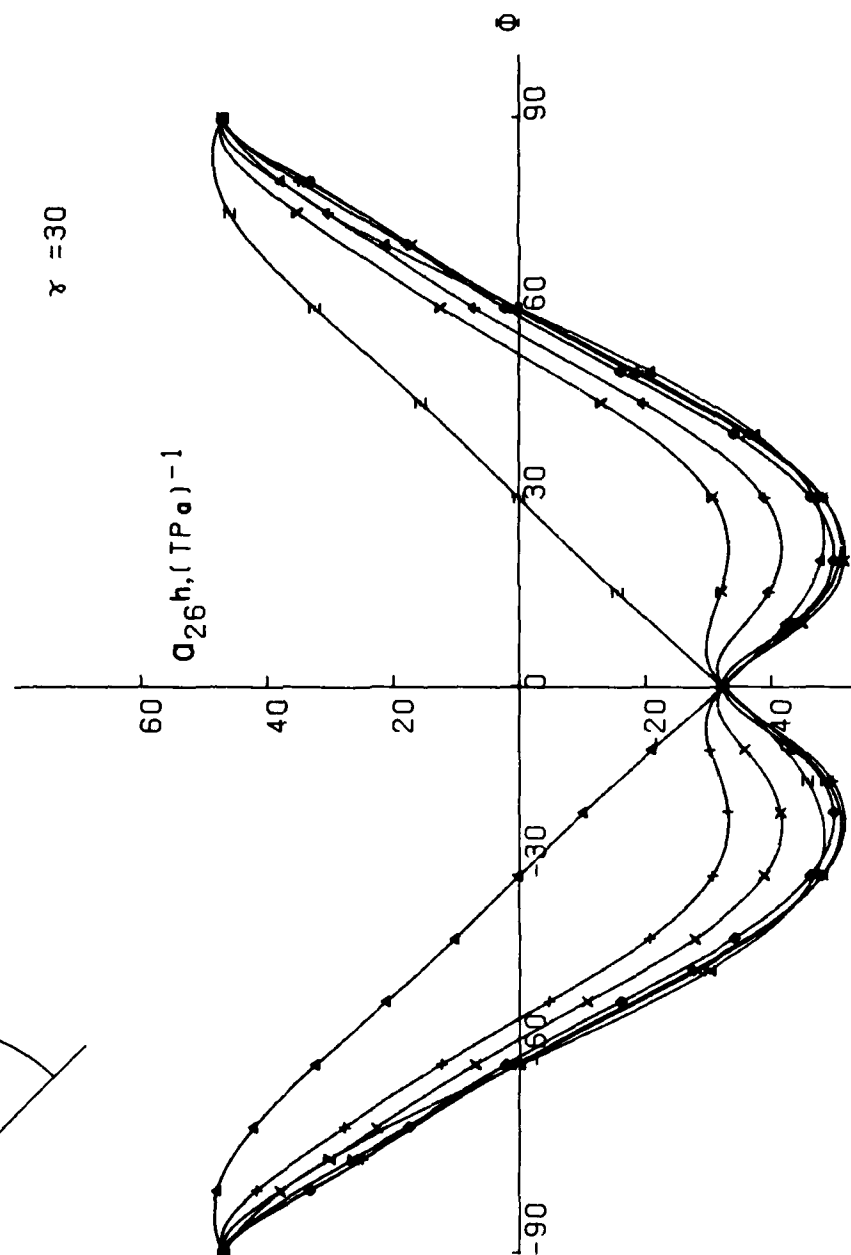
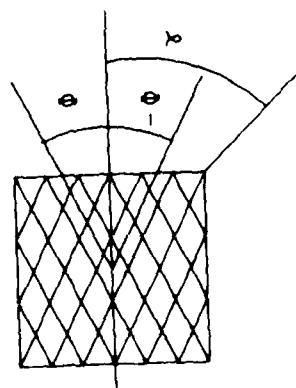


FIG.: 184



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\chi = 45$

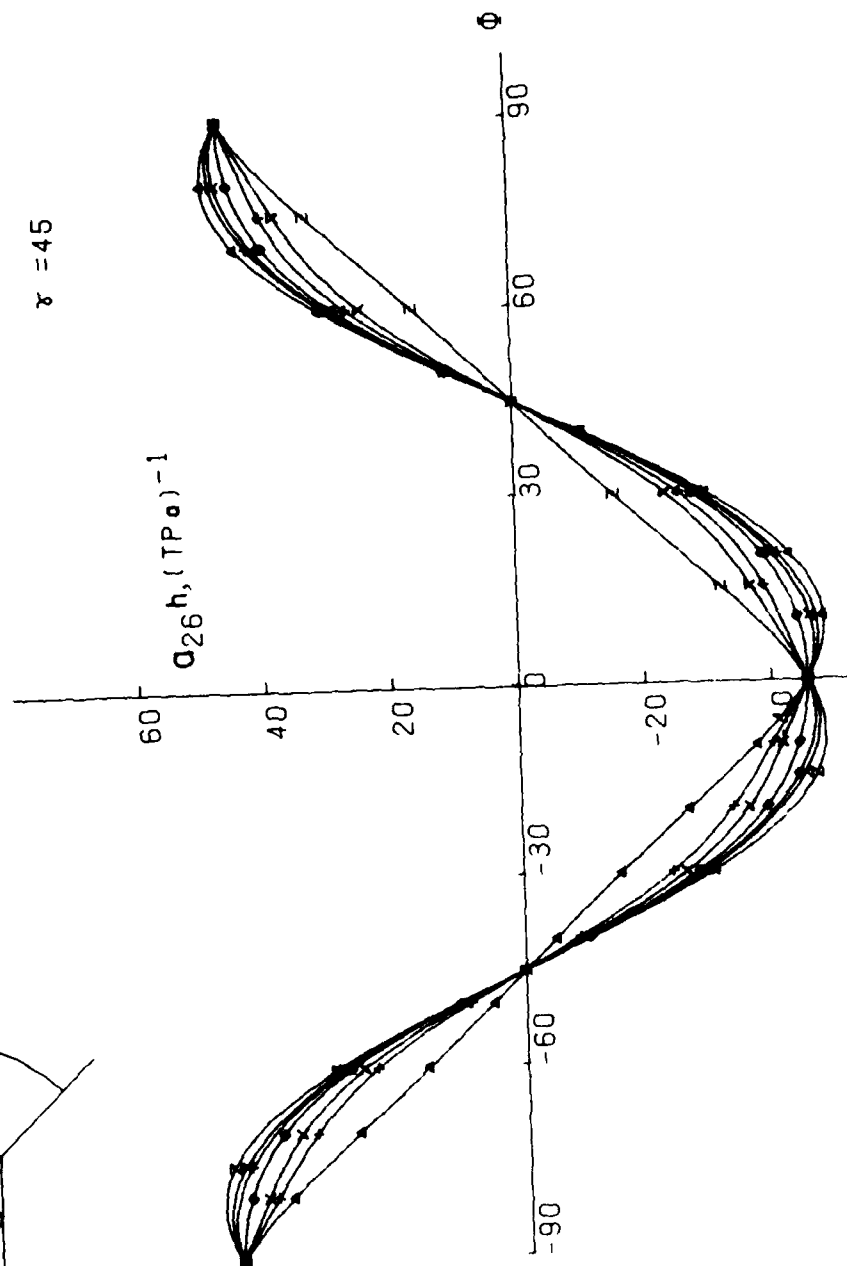
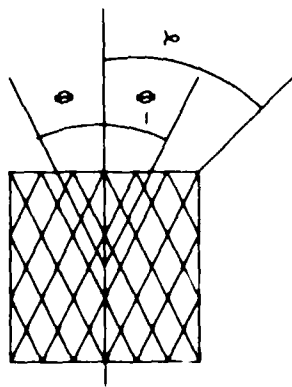


FIG.:185



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\chi = 60$

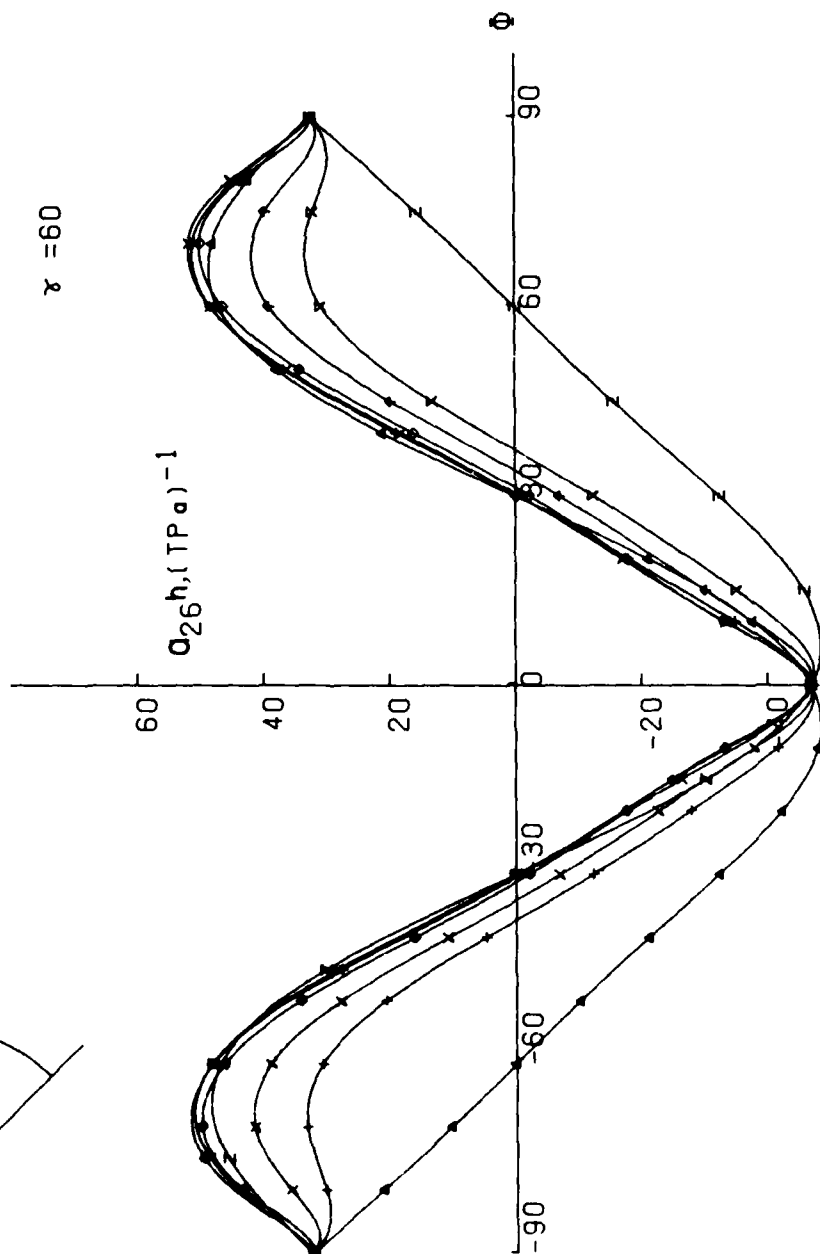
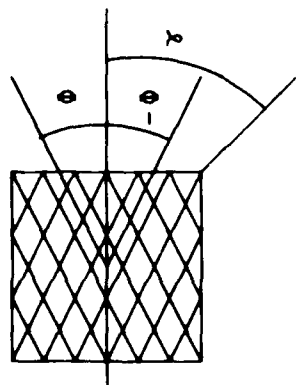


FIG.:186



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \blacktriangle (1/4)
 \times (1/9)
 ∇ (0/1)

$\gamma = 75$

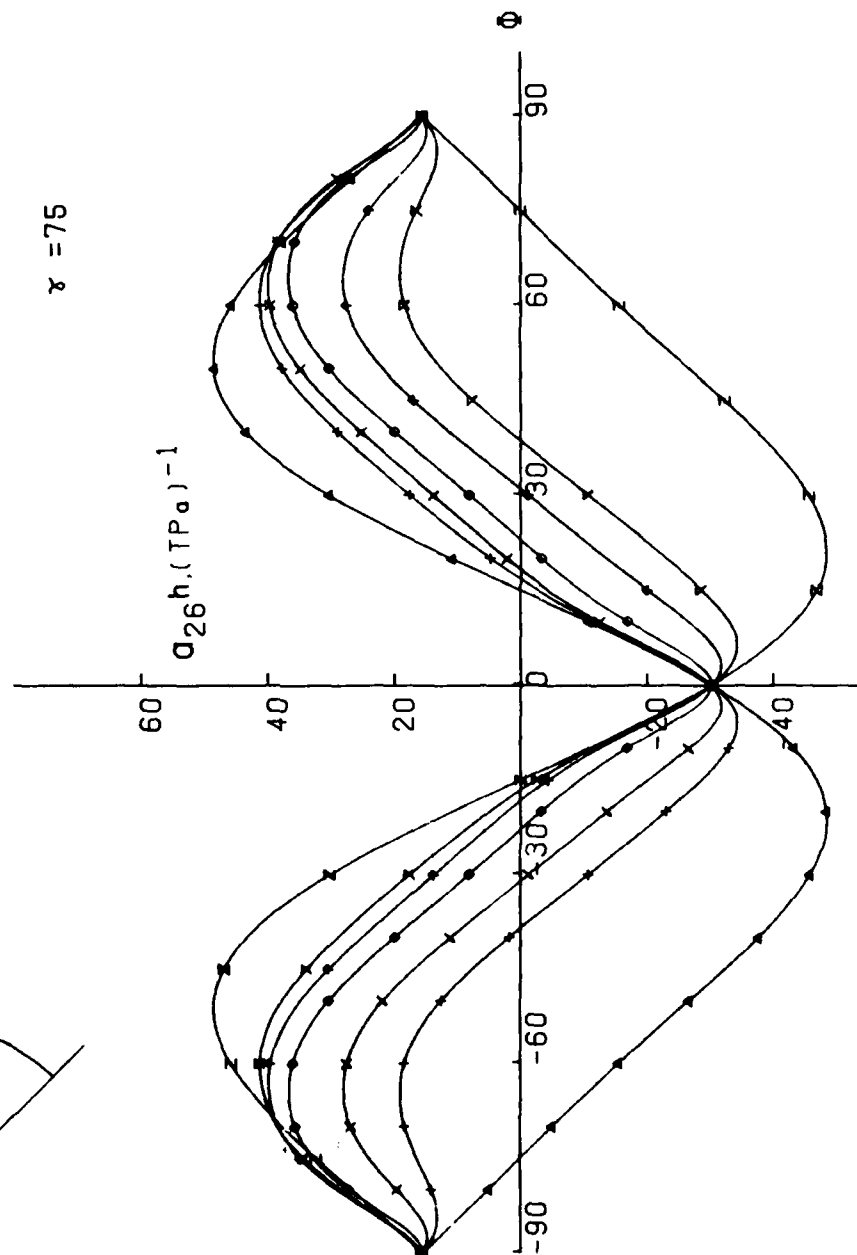


FIG.:187

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\Phi = 15$

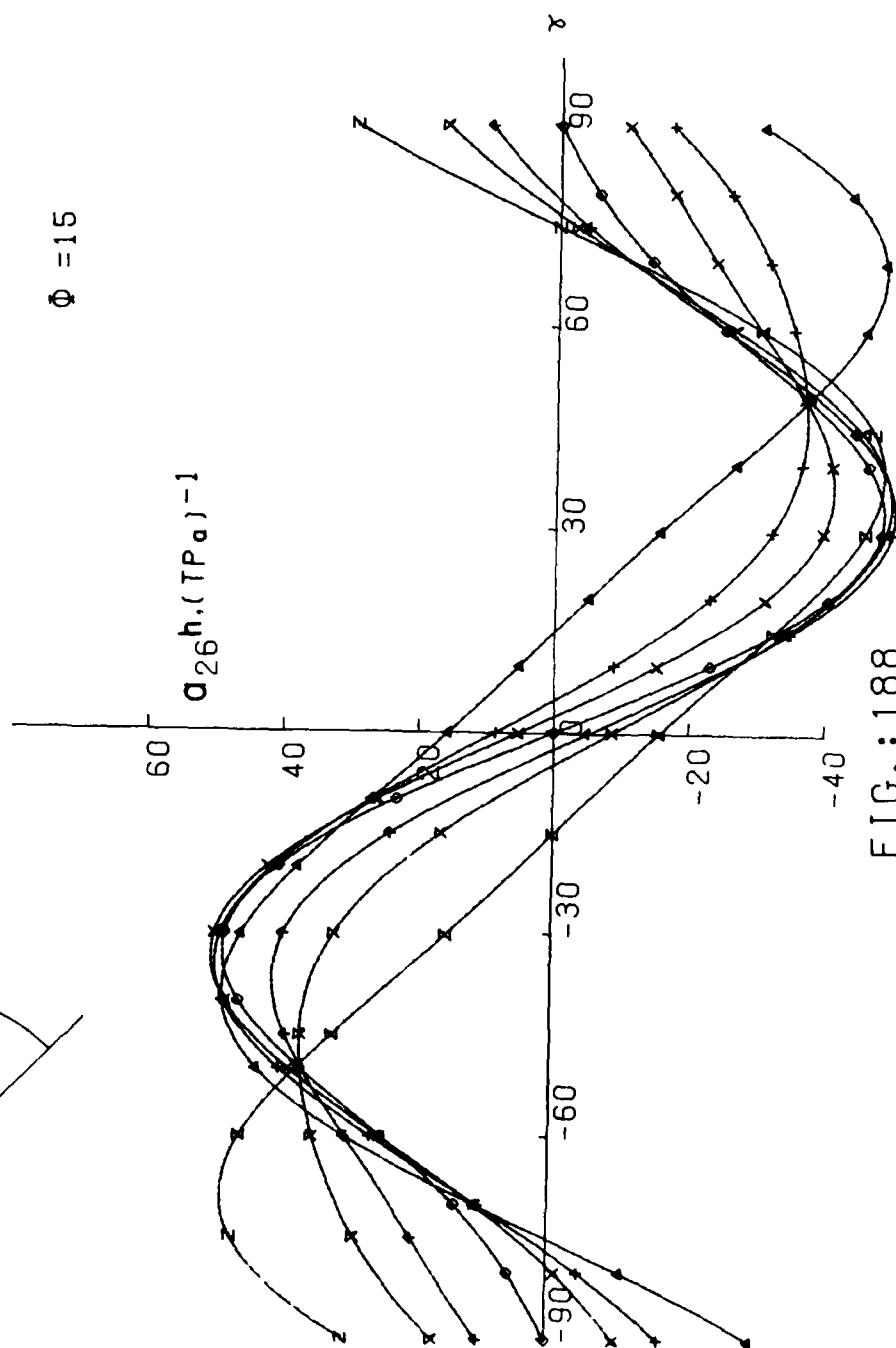
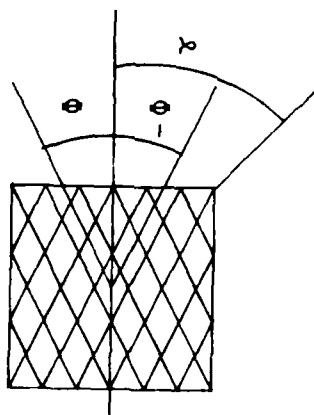
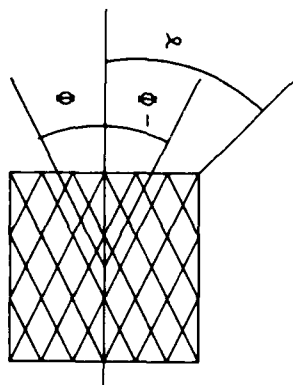


FIG.:188



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\Phi = 30$

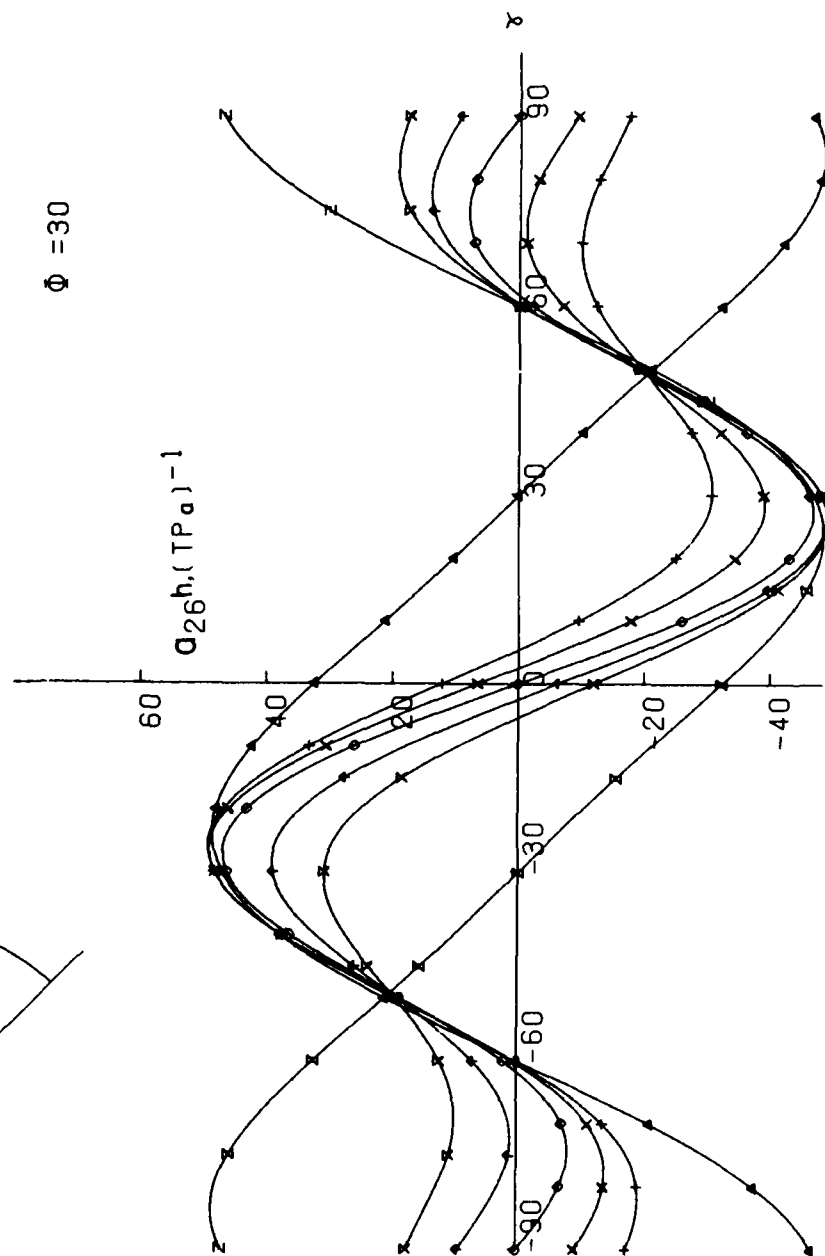
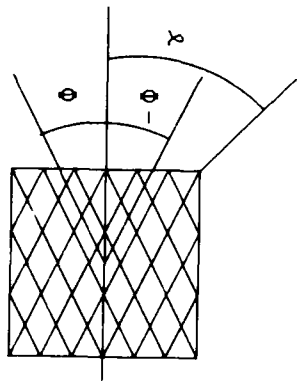


FIG.:189



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\phi = 45$

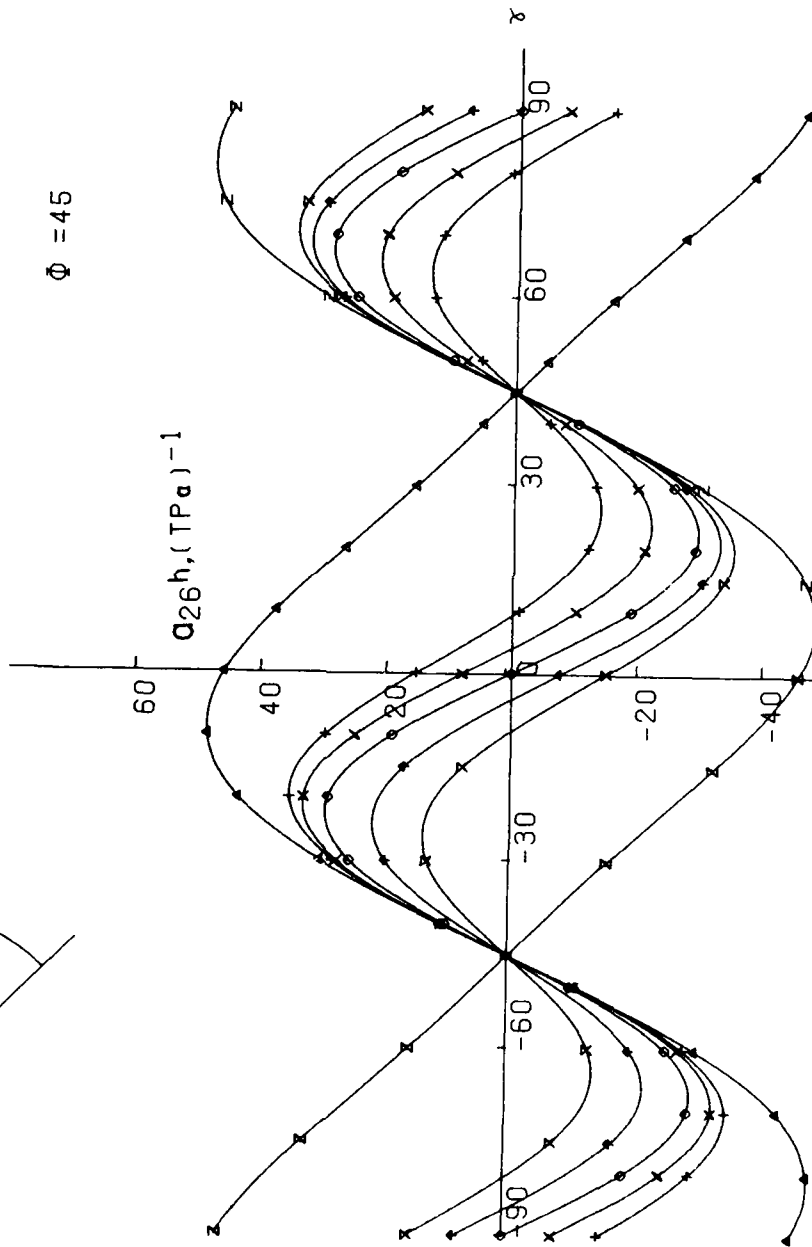


FIG.:190

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\Phi = 60$

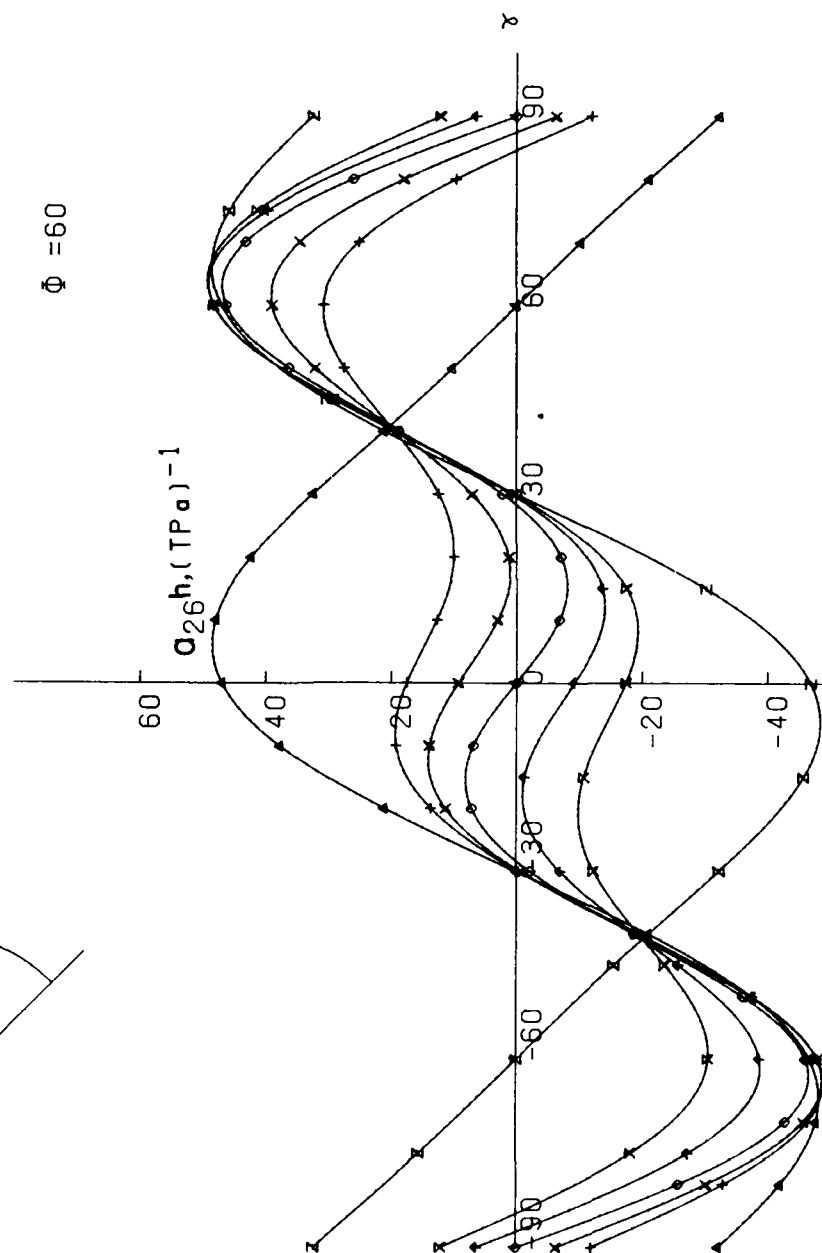
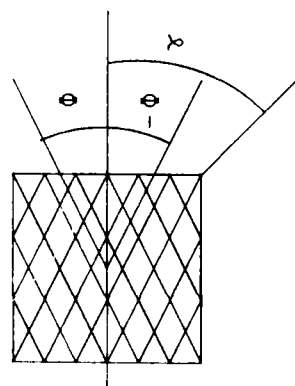
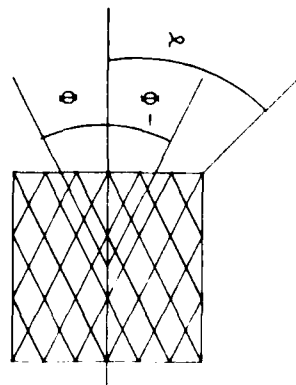


FIG.:191



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \times (1/9)
 Σ (0/1)
 $\phi = 75$

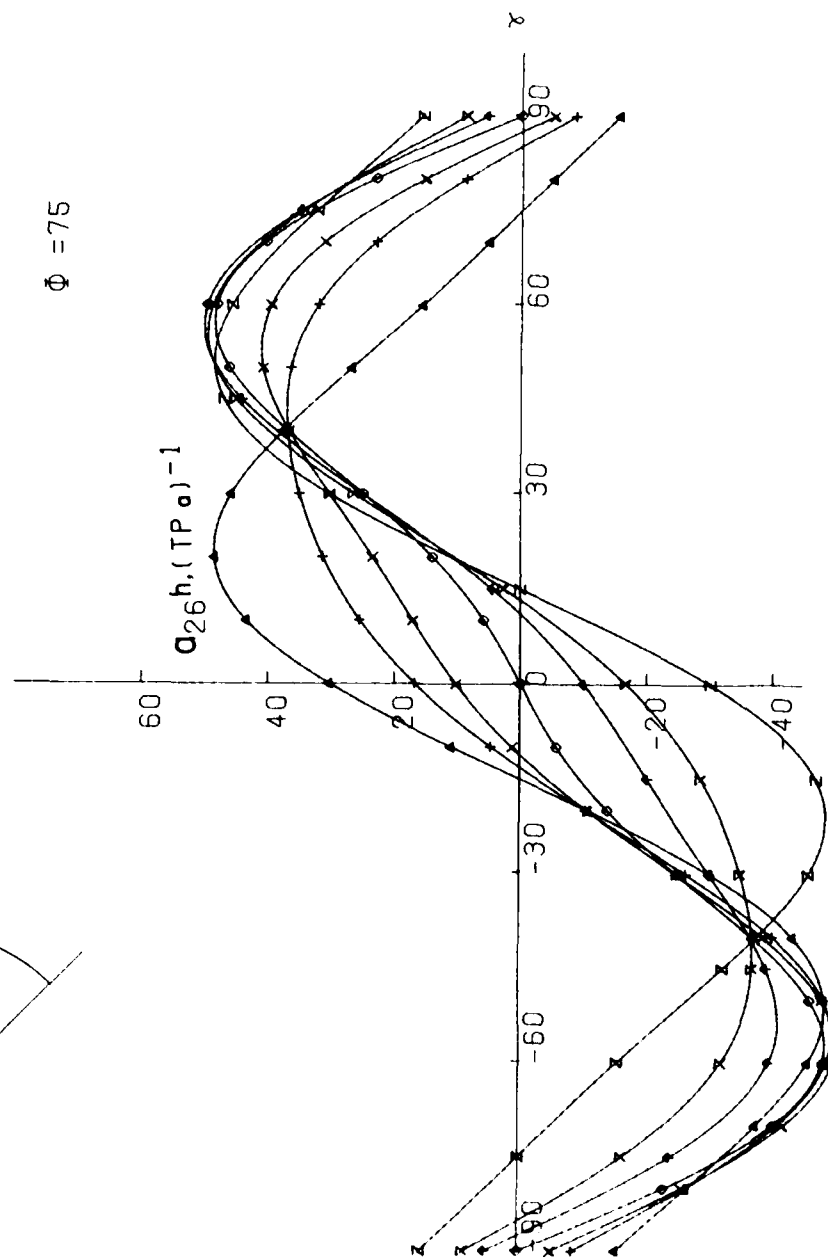
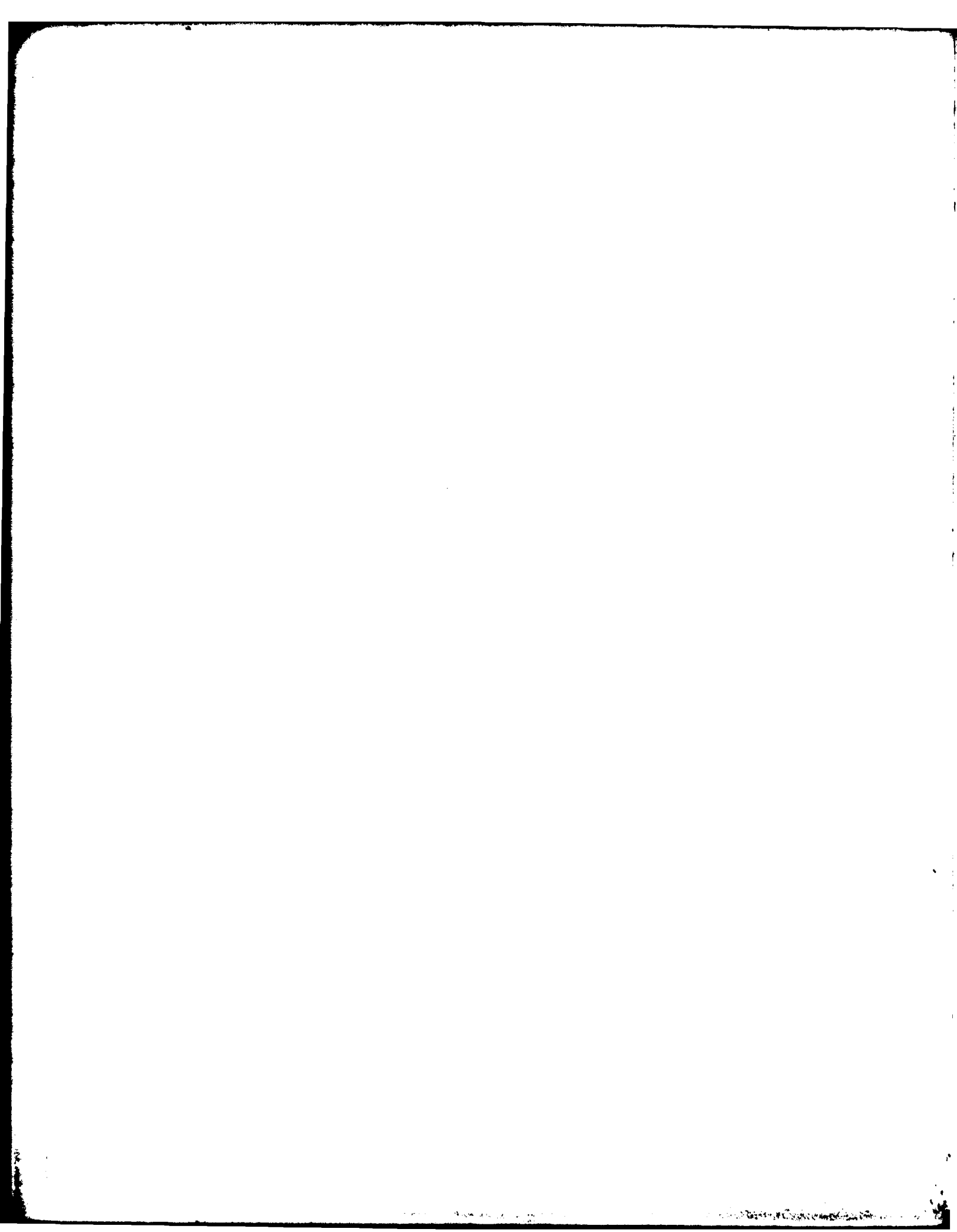


FIG.:192



INPLANE COUPLING RATIOS FOR VARIOUS LAMINATES

PARAMETER	FIGURE NOS.
ν_{21}^0	193-208
ν_{61}^0	209-224
ν_{12}^0	225-240
ν_{62}^0	241-256
ν_{16}^0	257-272
ν_{26}^0	273-288

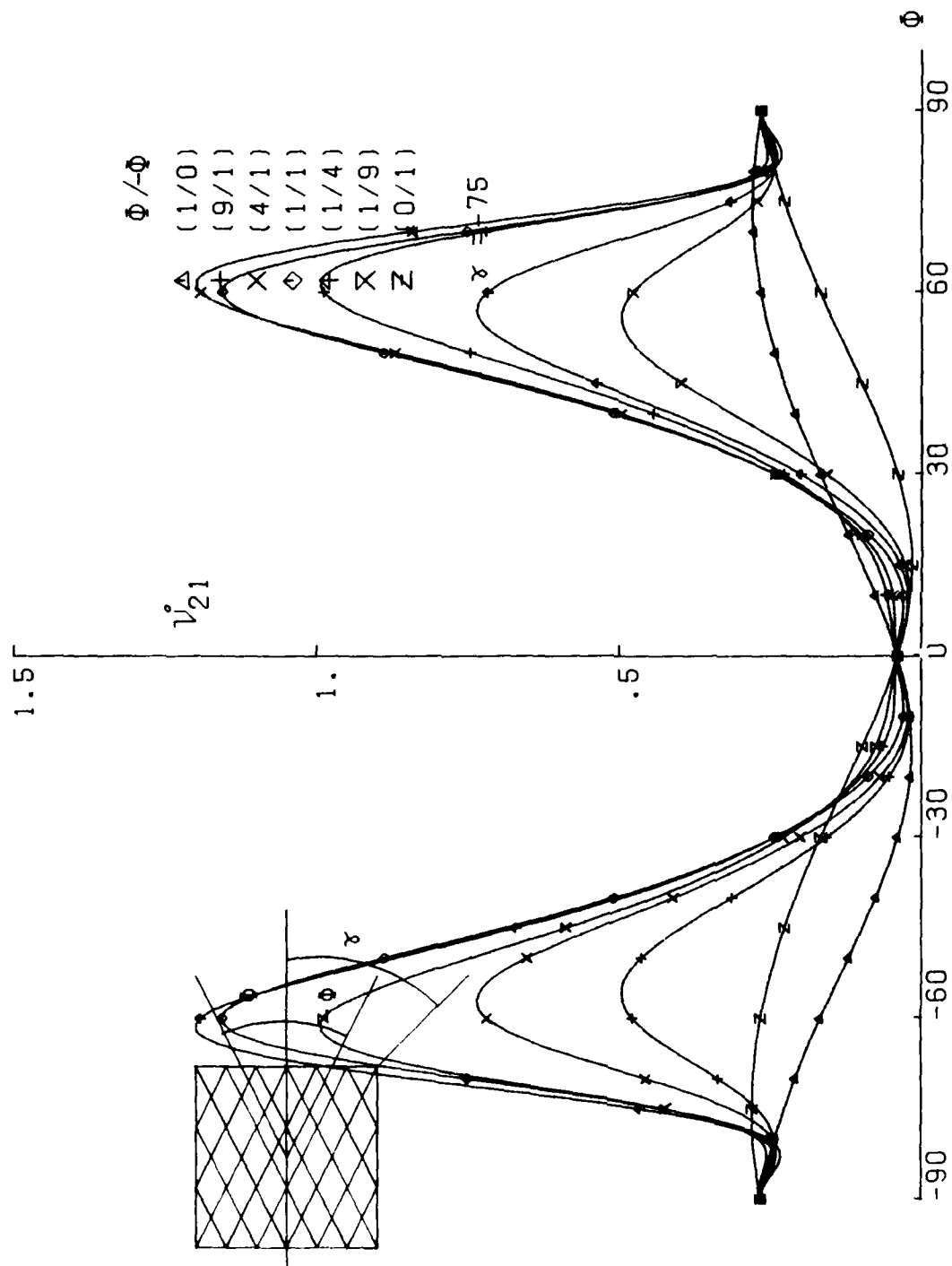


FIG.:193

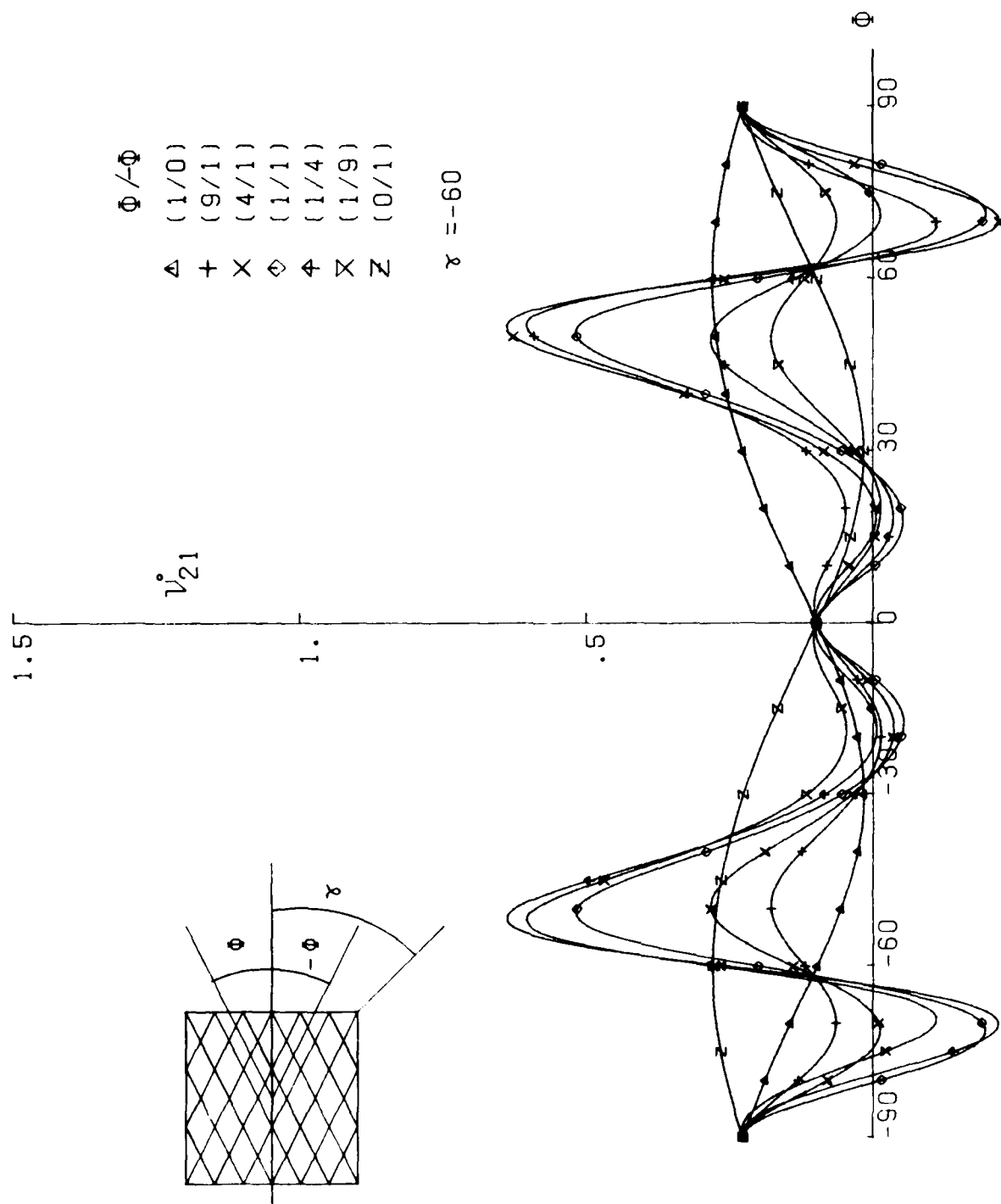


FIG.:194

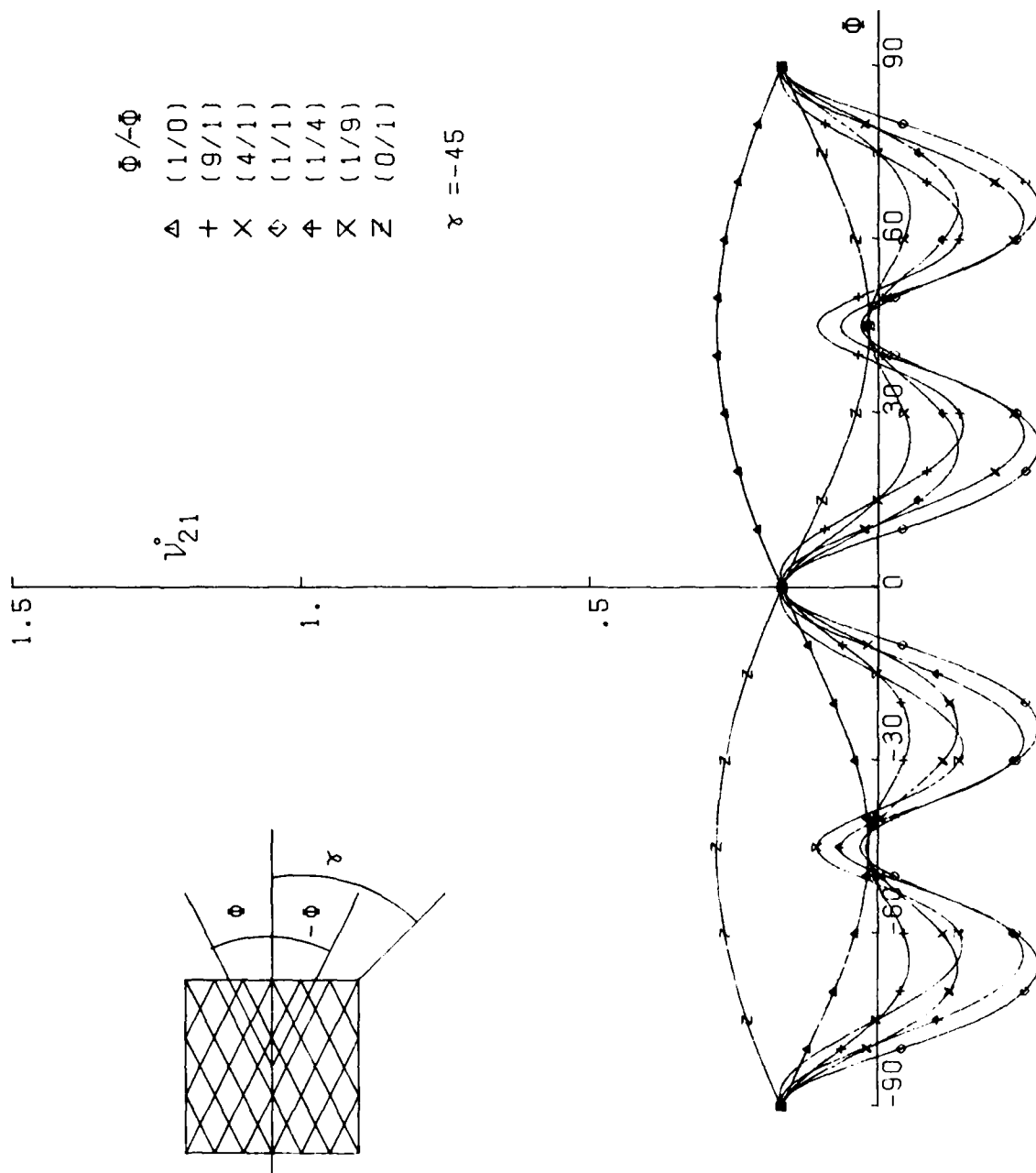


FIG.:195

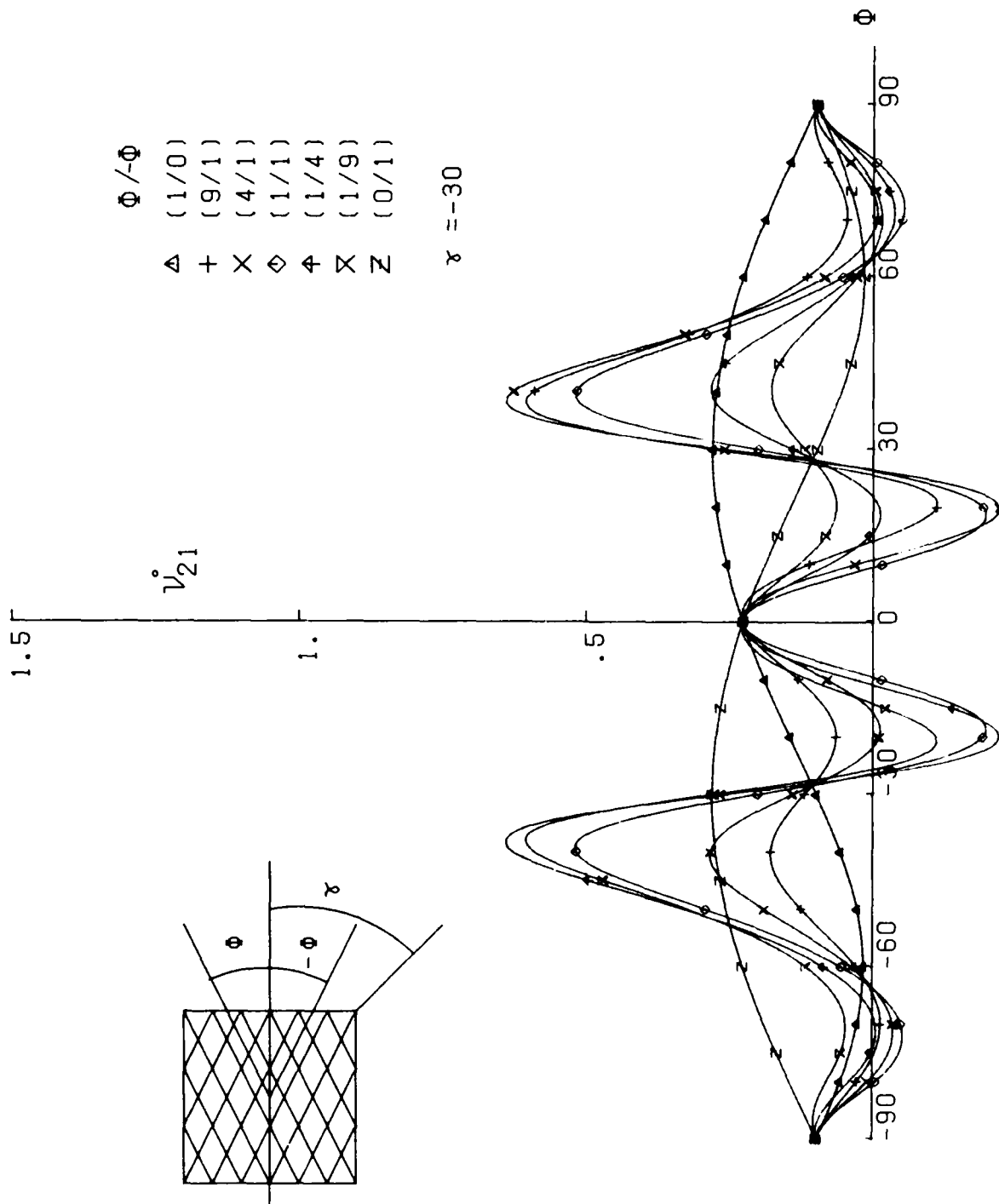


FIG.:196

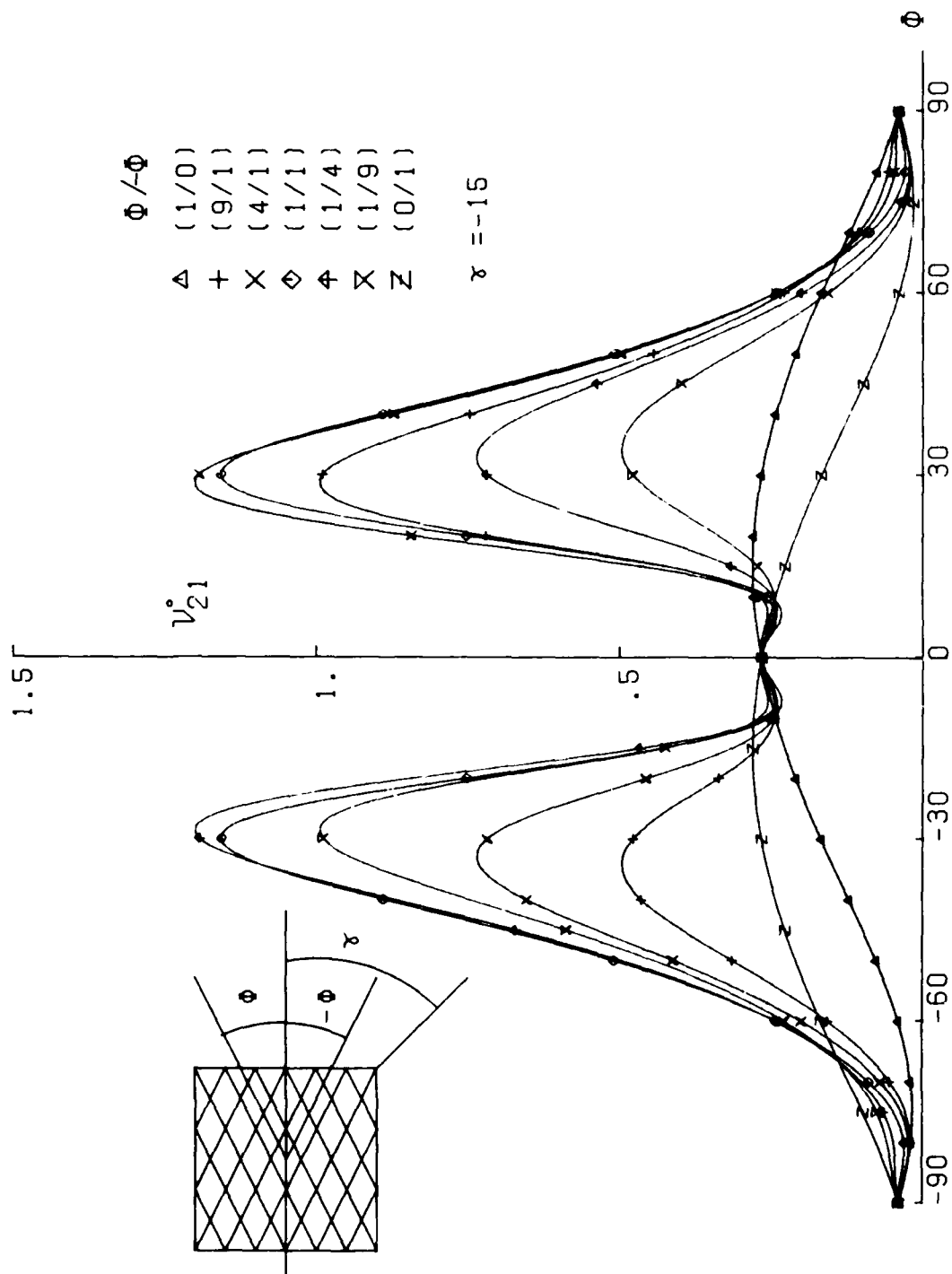


FIG.:197

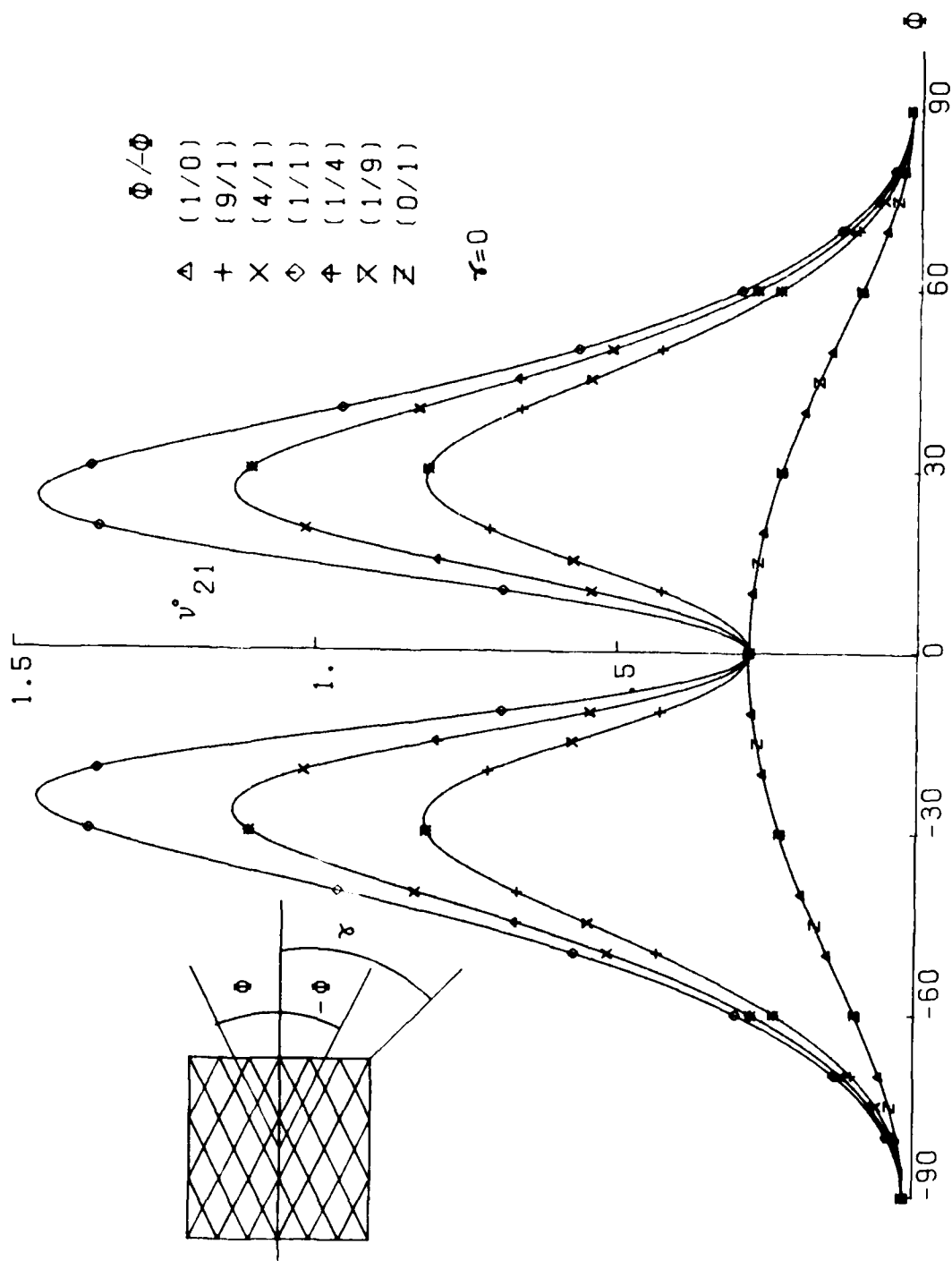


FIG.:198

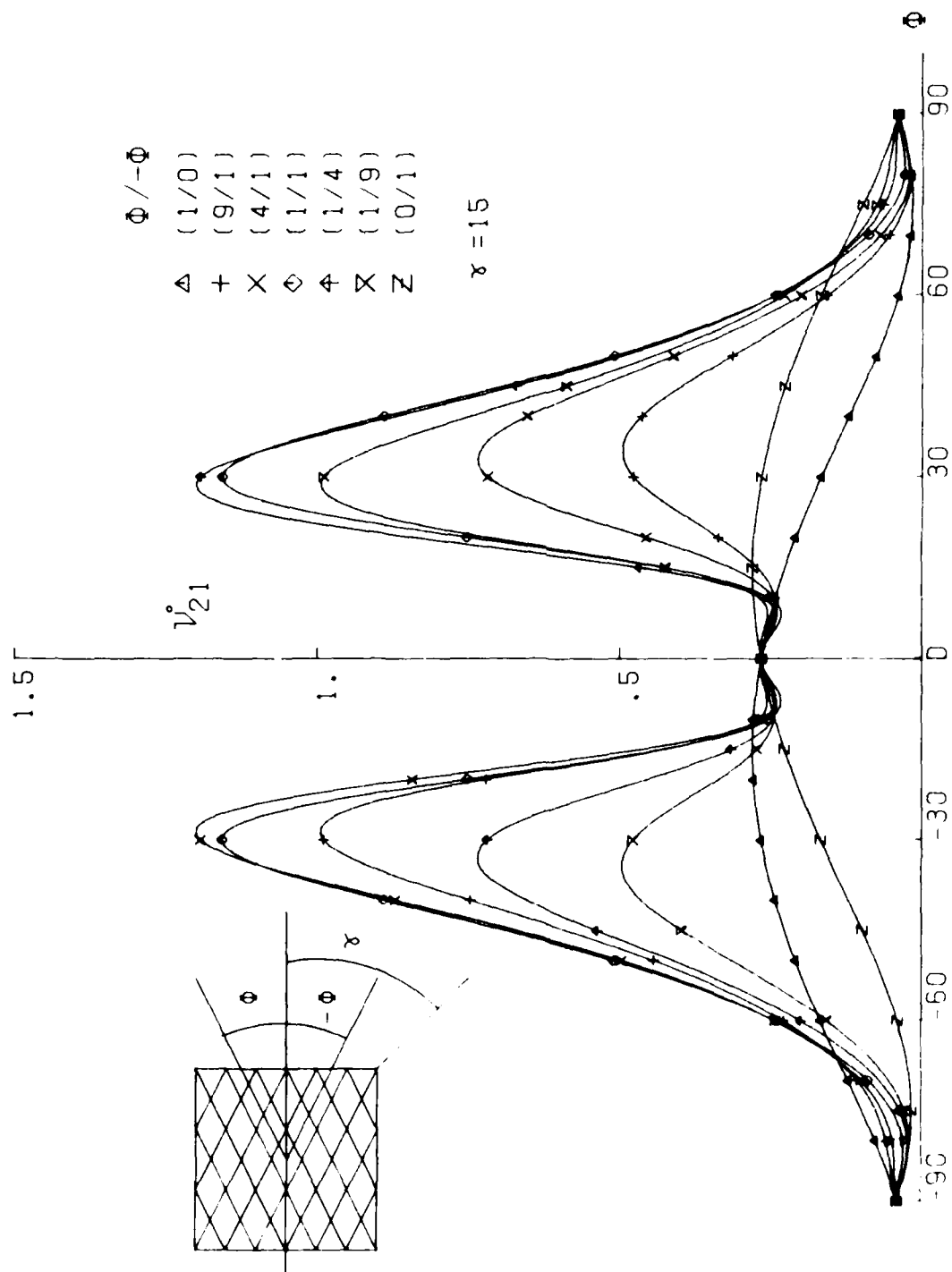


FIG.:199

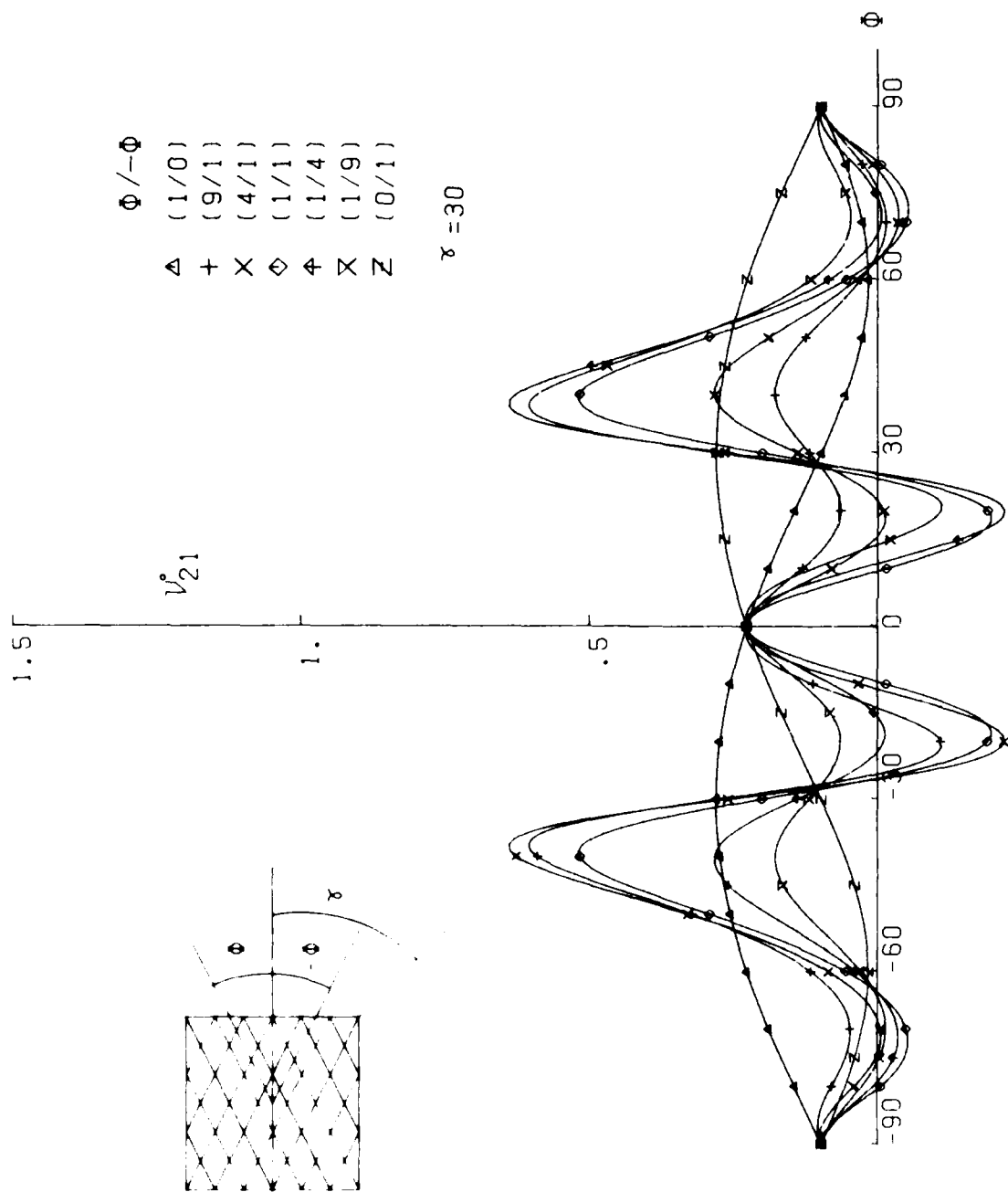


FIG.:200

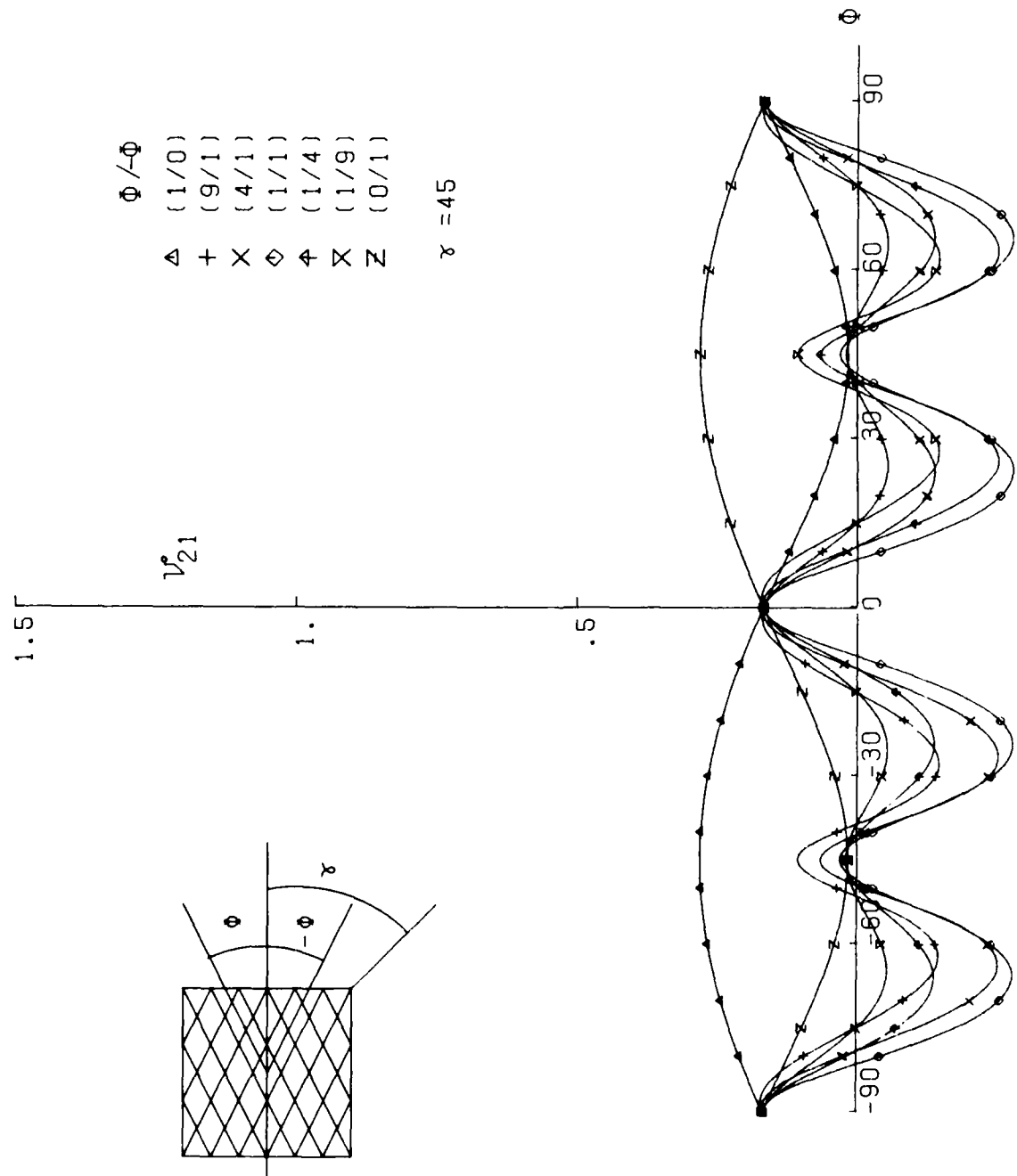


FIG.:201

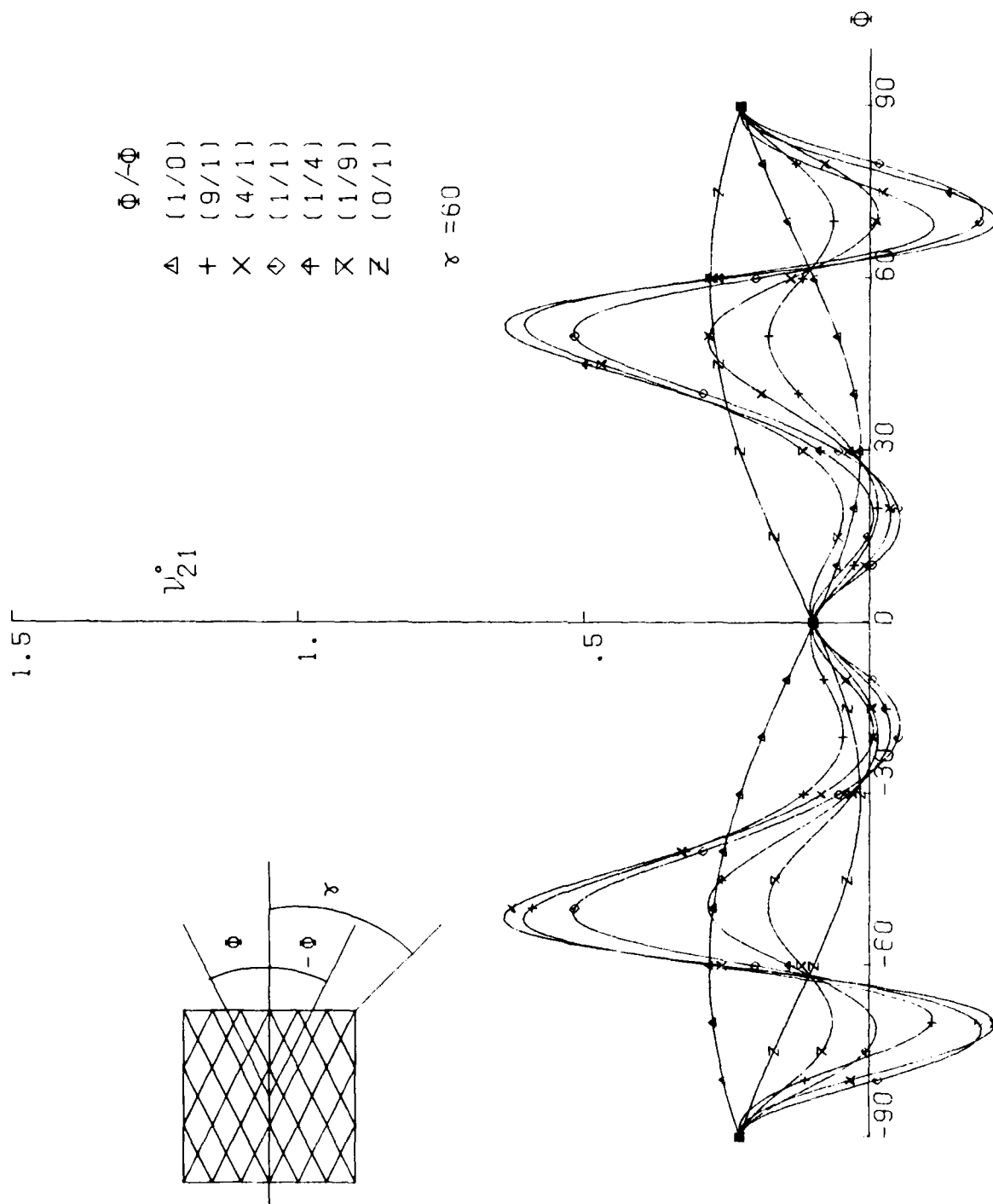


FIG.:202

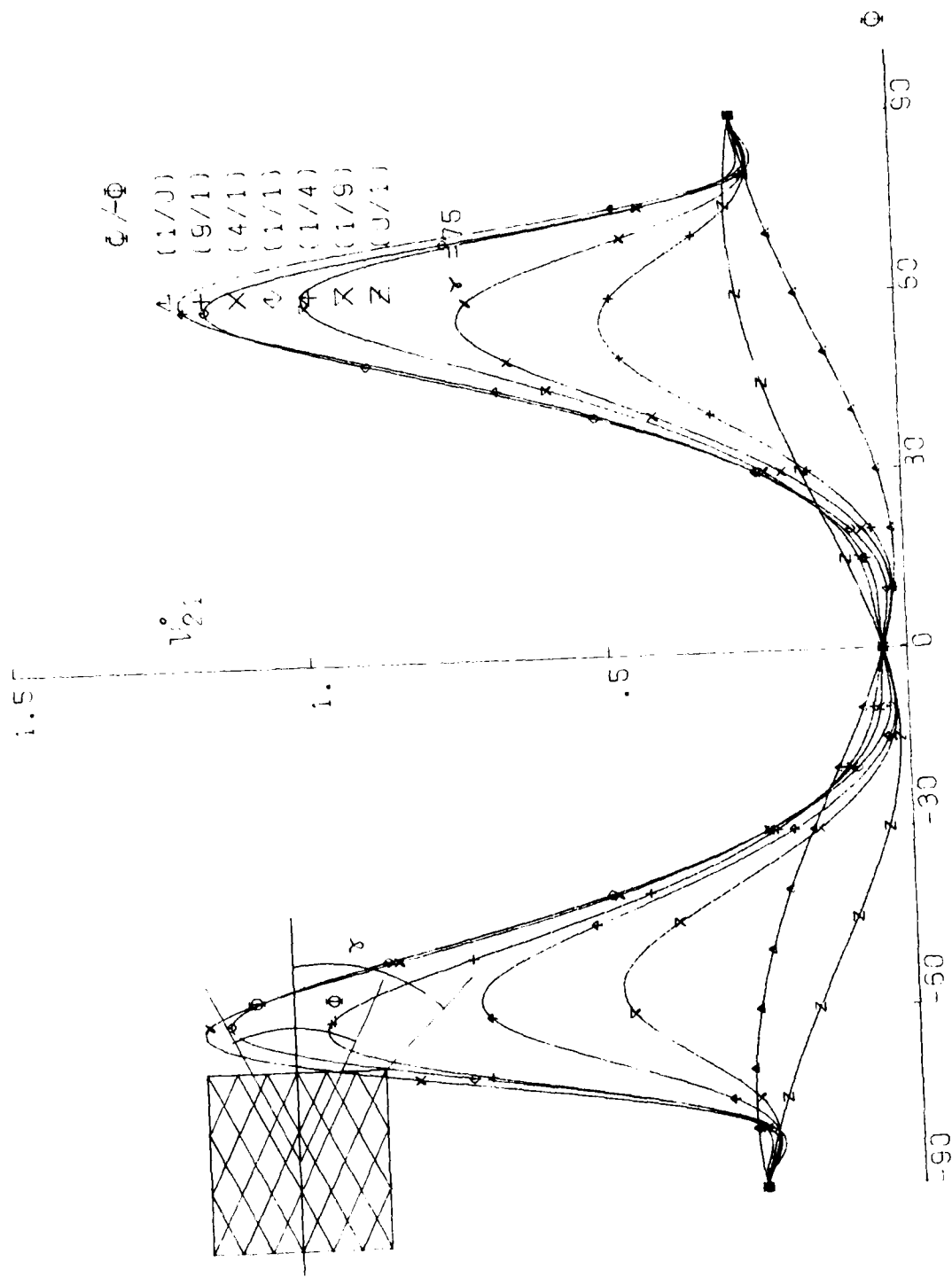


FIG.:203

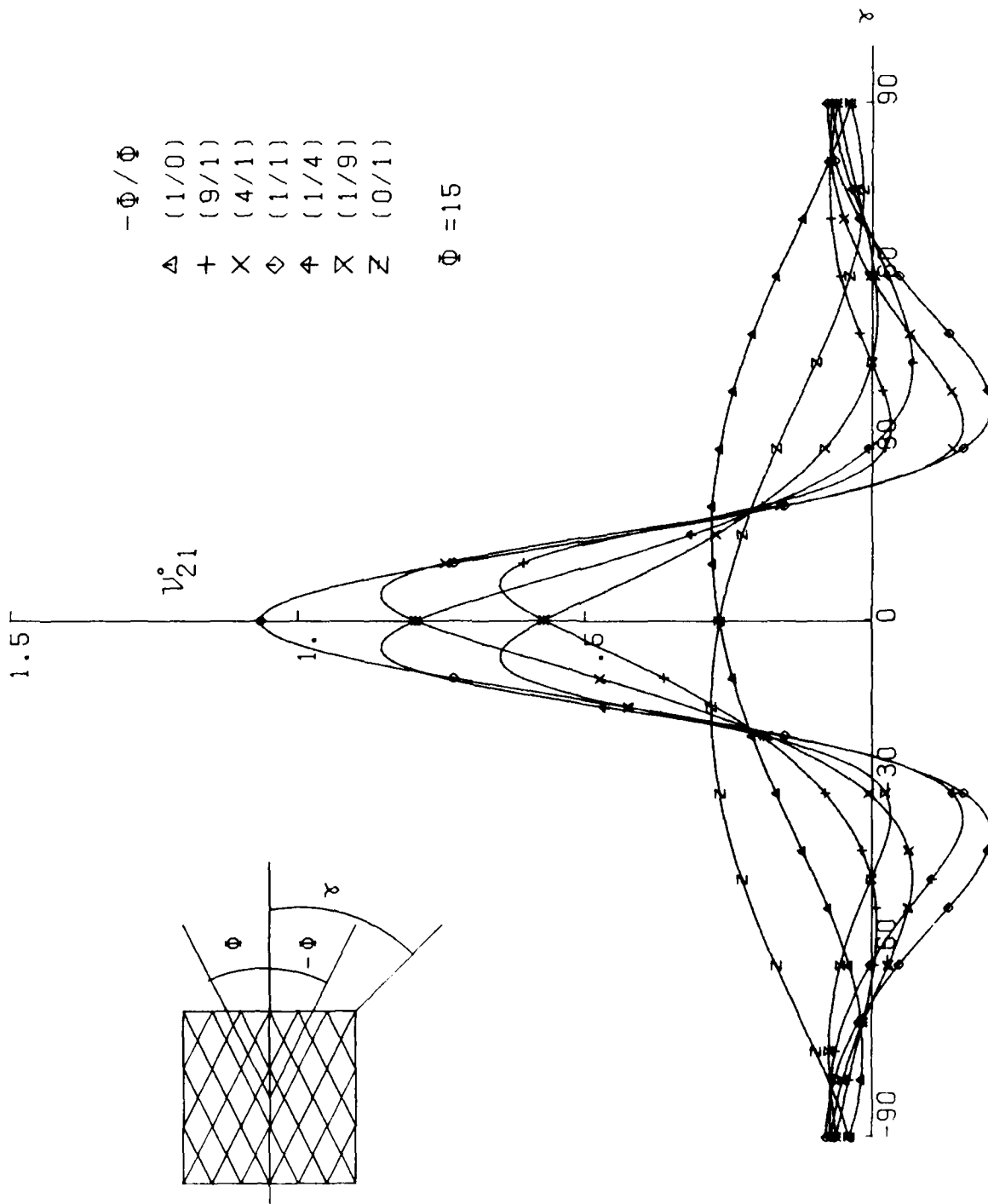


FIG.:204

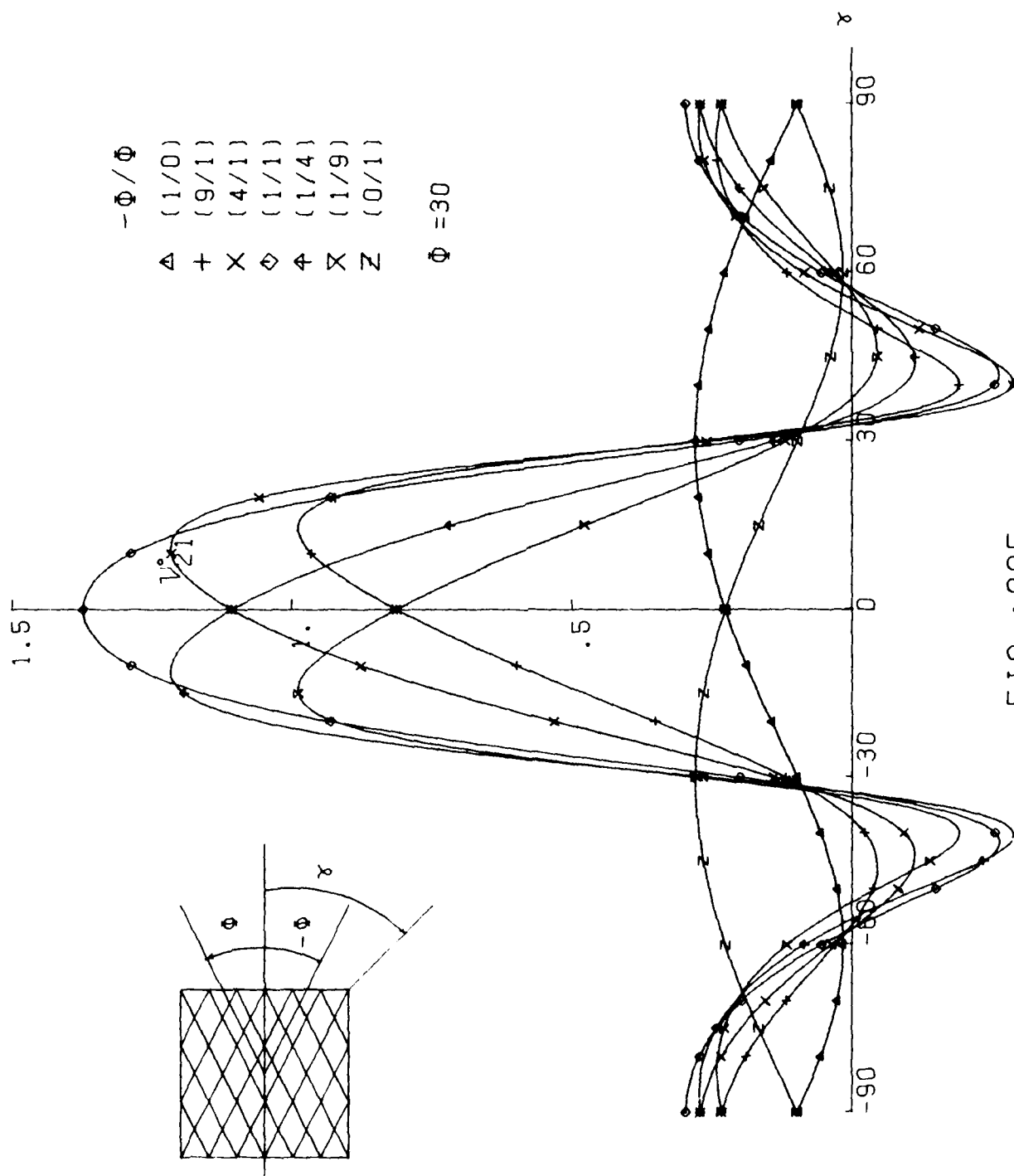


FIG.:205

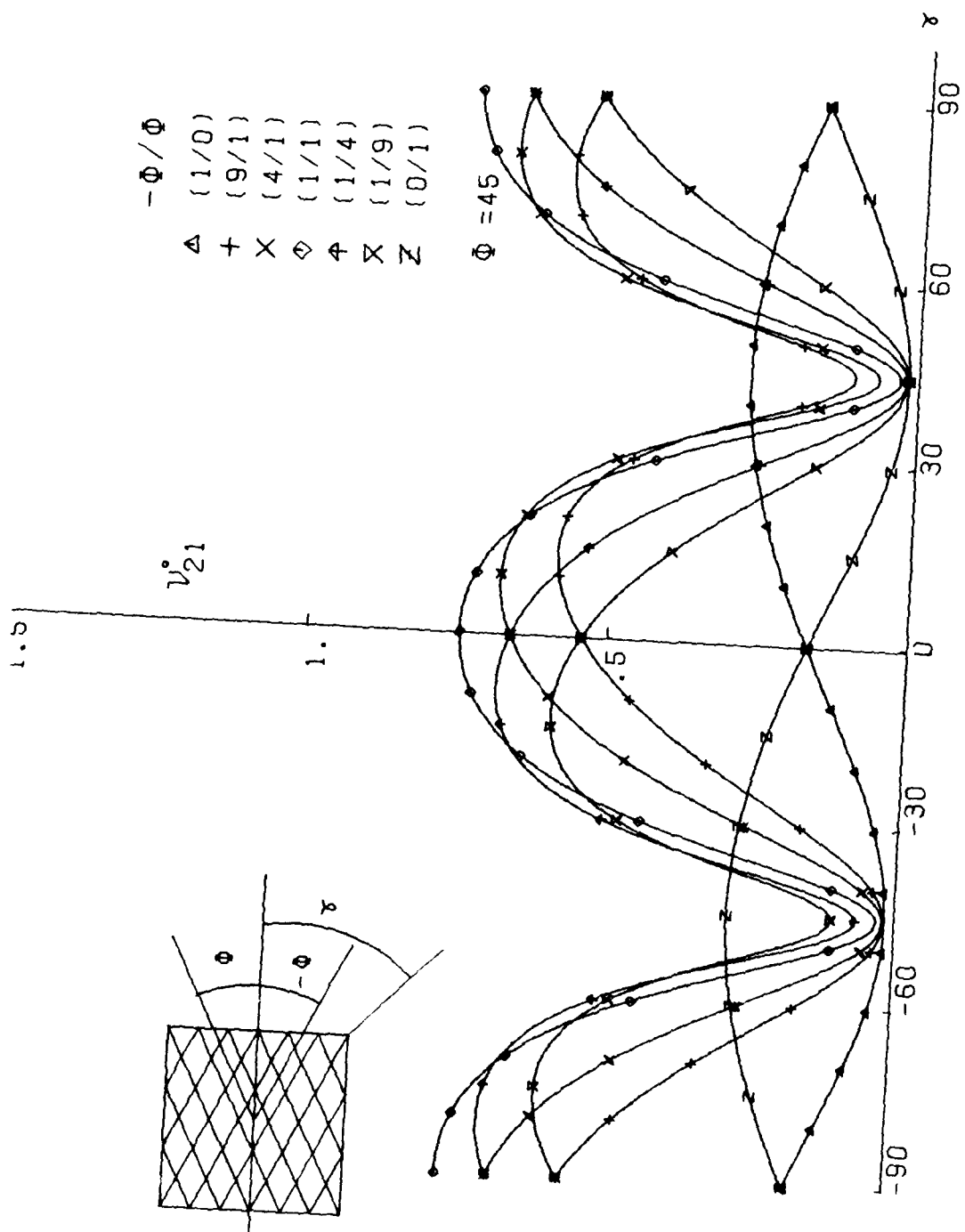


FIG.:206

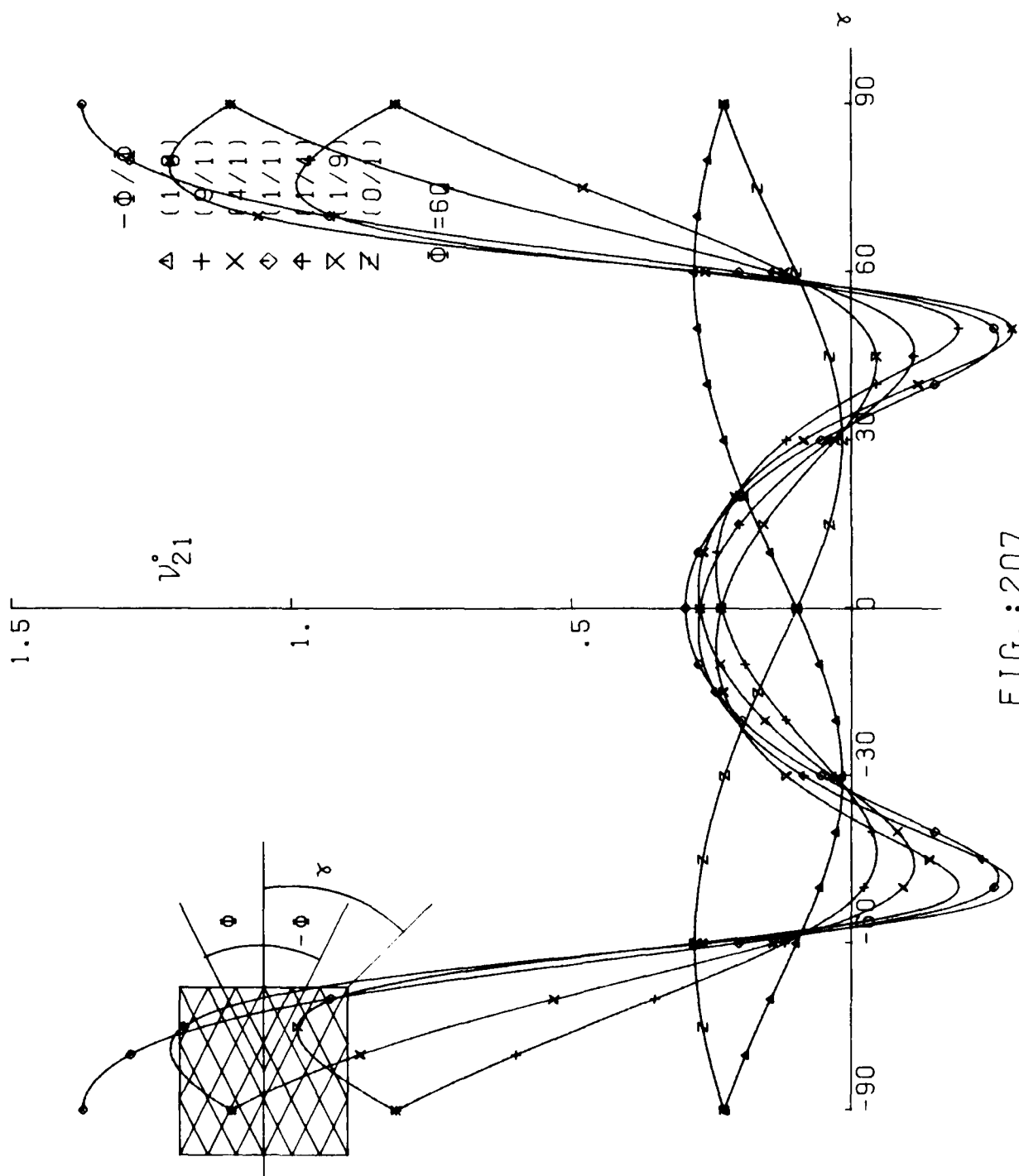


FIG.: 207

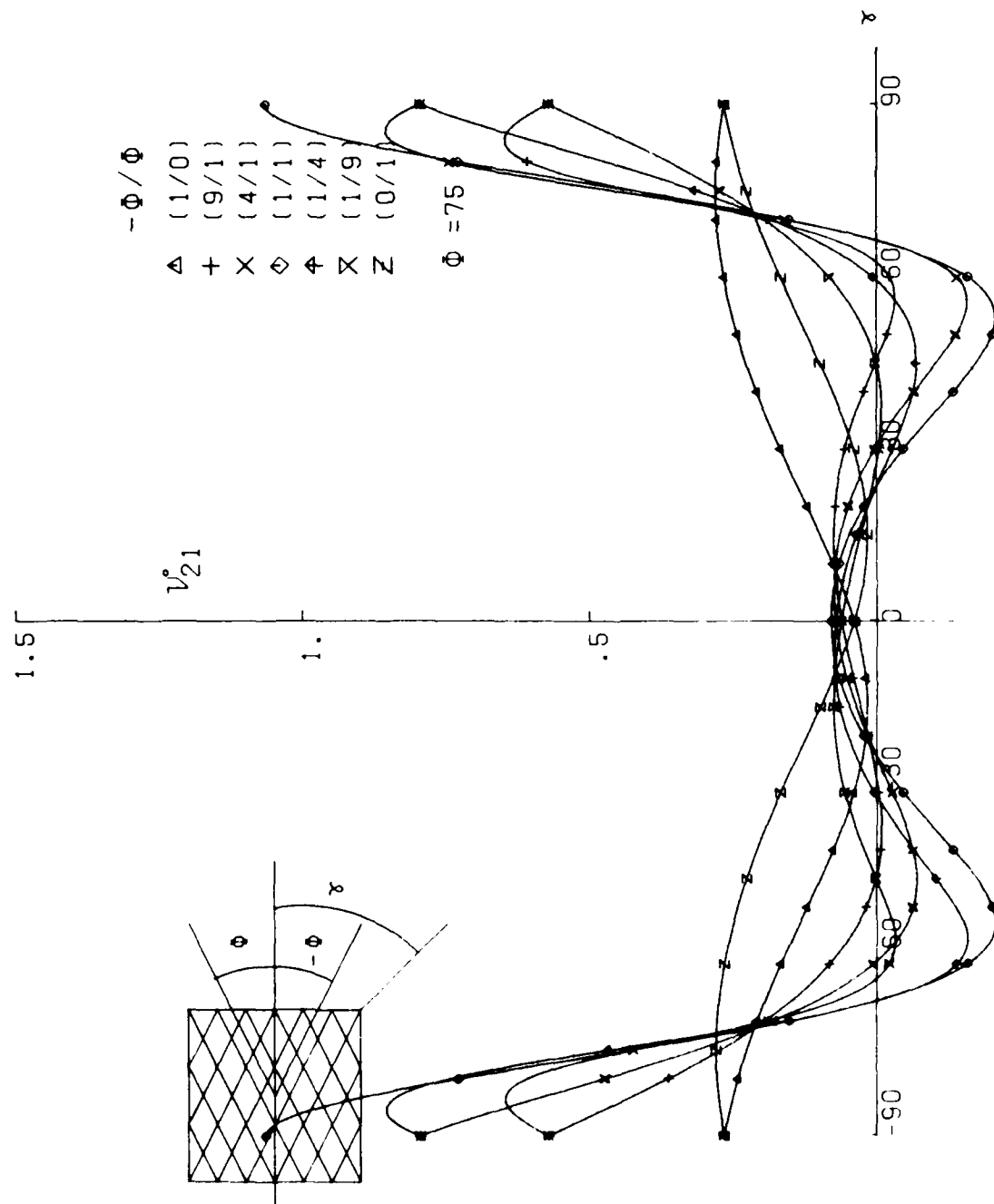
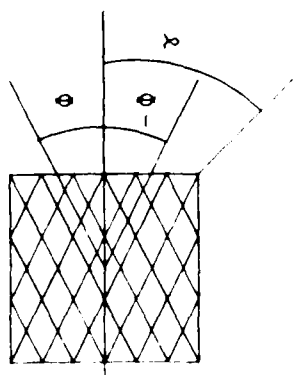


FIG.:208

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Z (0/1)

$\gamma = -75$



ν_{61}^*

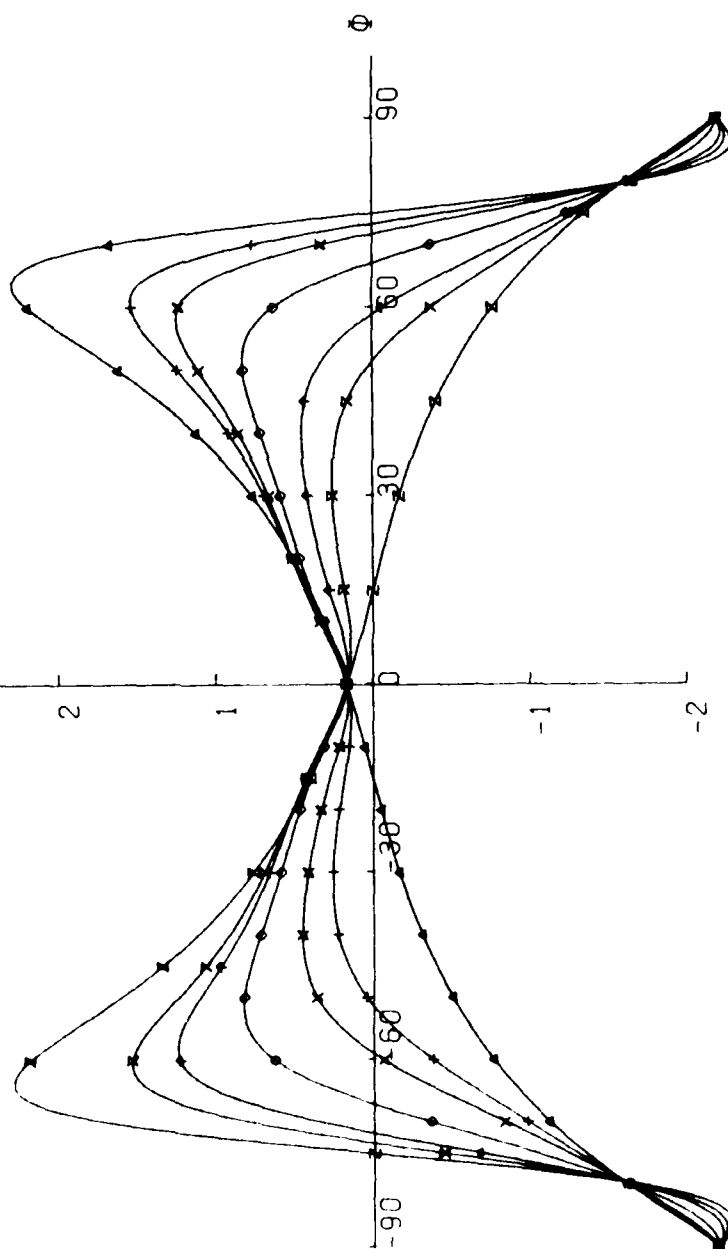
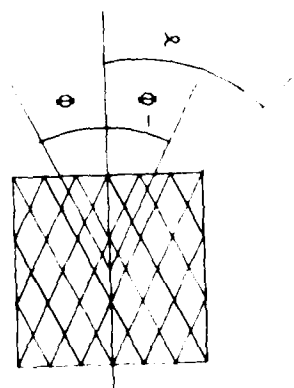


FIG.:209

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\chi = -60$



ψ_6

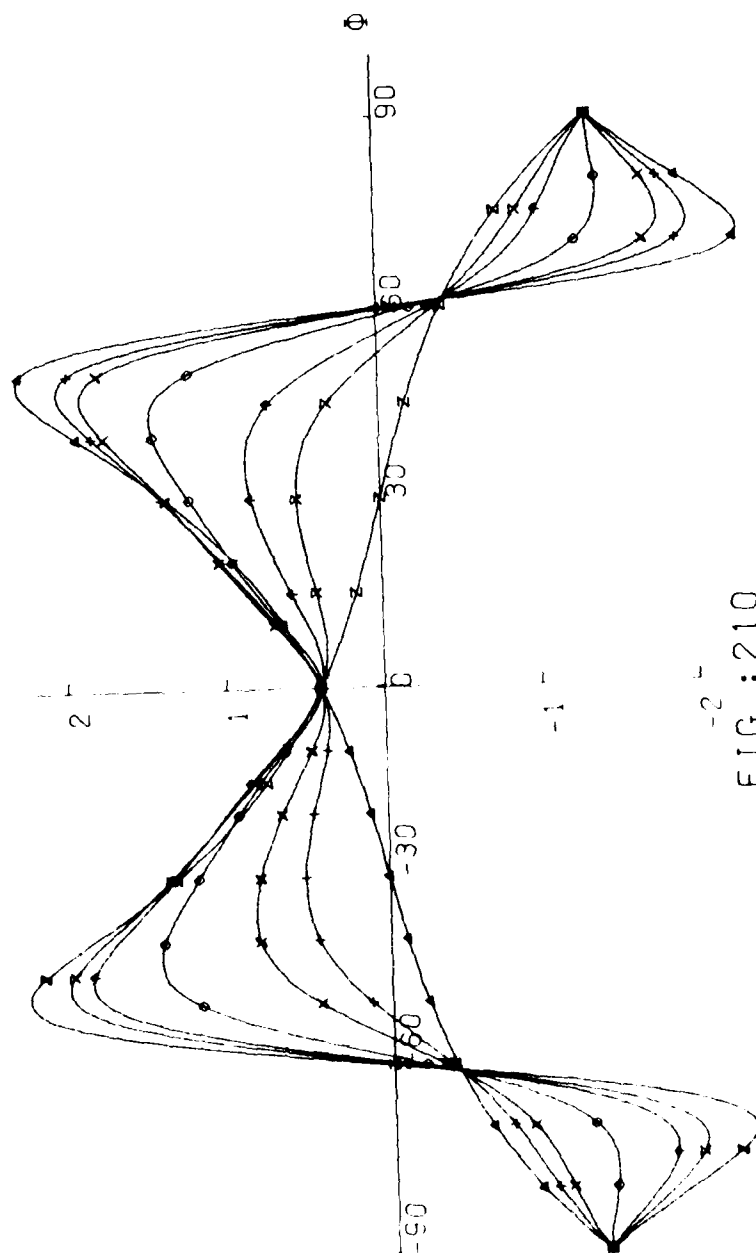
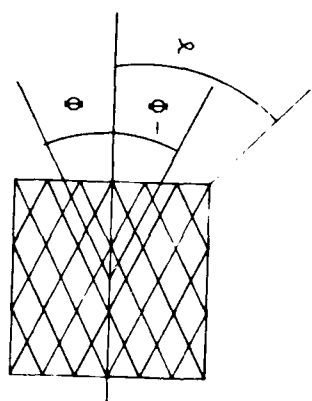


FIG.:210

Φ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = -45$



ν_{61}

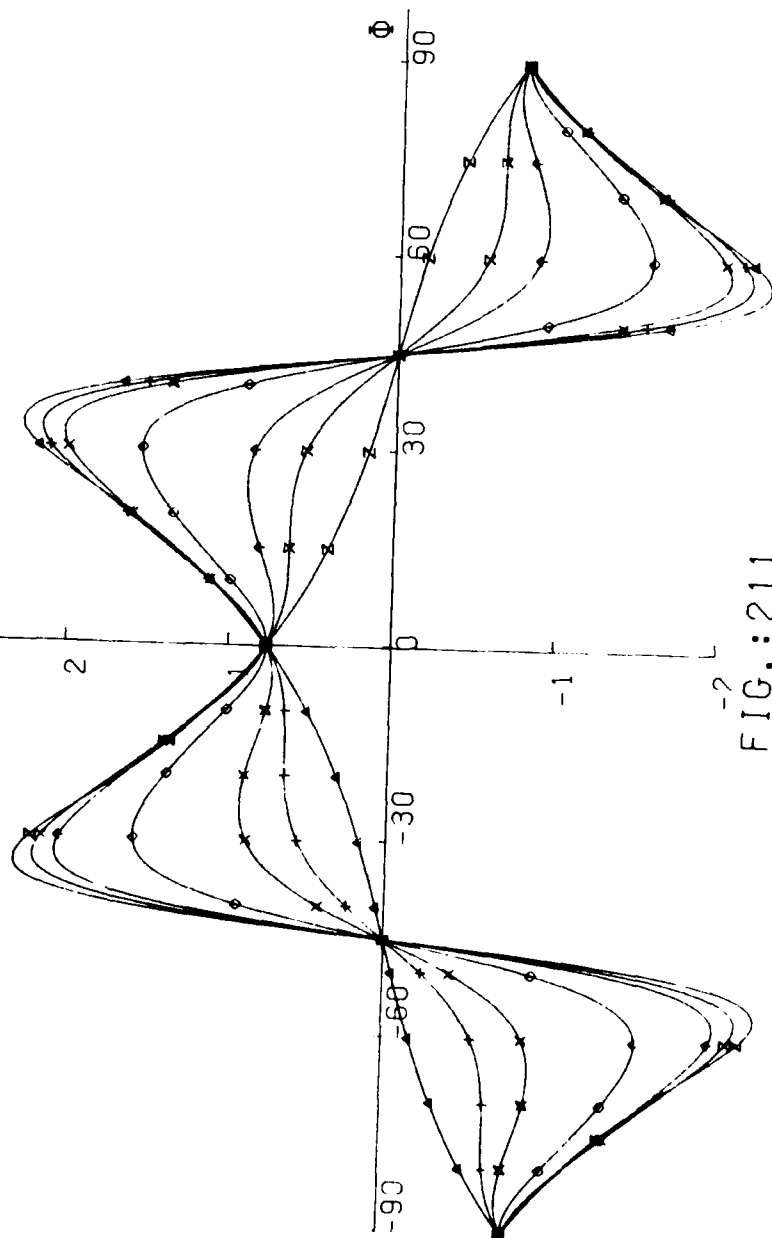
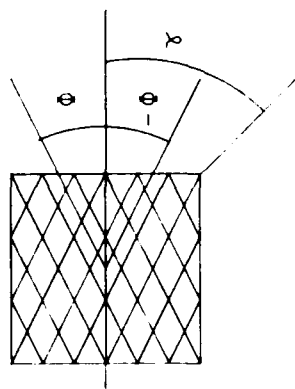


FIG.:211

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4,1)
 \circ (1,1)
 \diamond (1/4)
 ∇ (1,9)
 \square (0/1)

$\gamma = -30$



15°

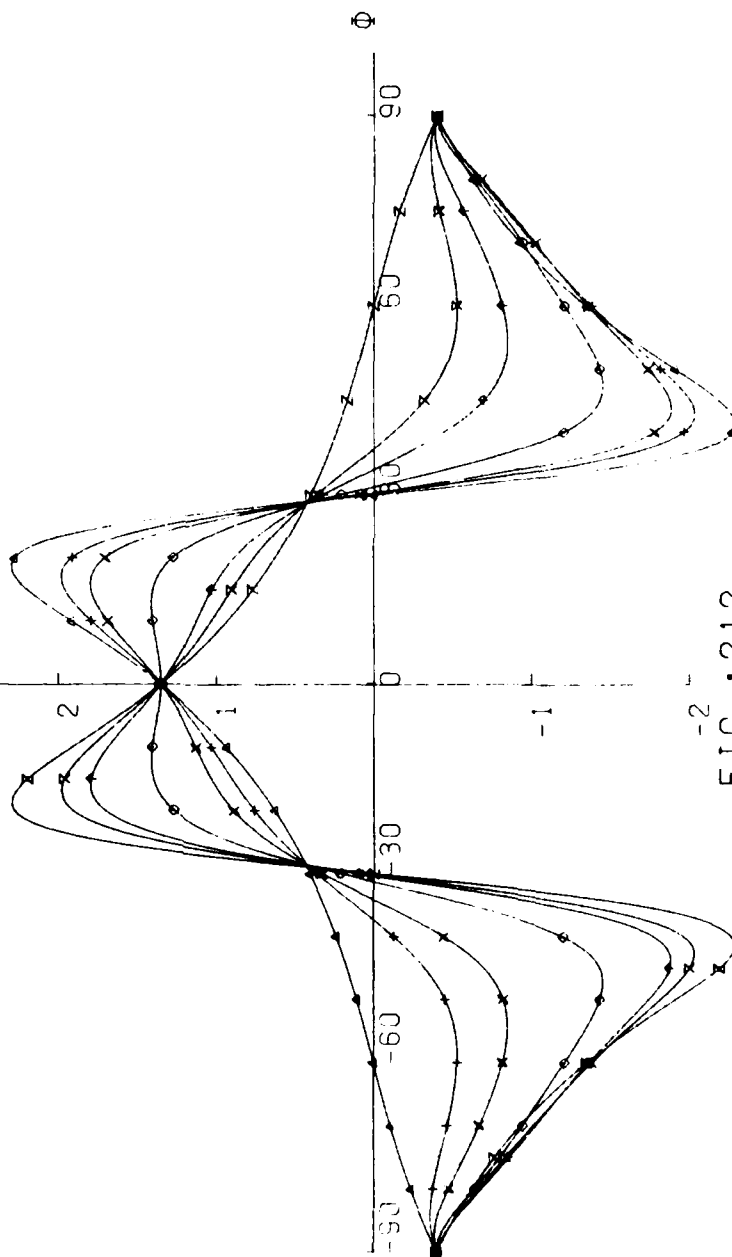


FIG.:212

$\Phi / -\Phi$
 Δ (1/3)
 $+$ (9/1)
 \times (4/1)
 \circ (1/1)
 \diamond (1/4)
 \times (1/9)
 \square (0/1)
 $\gamma = -15$

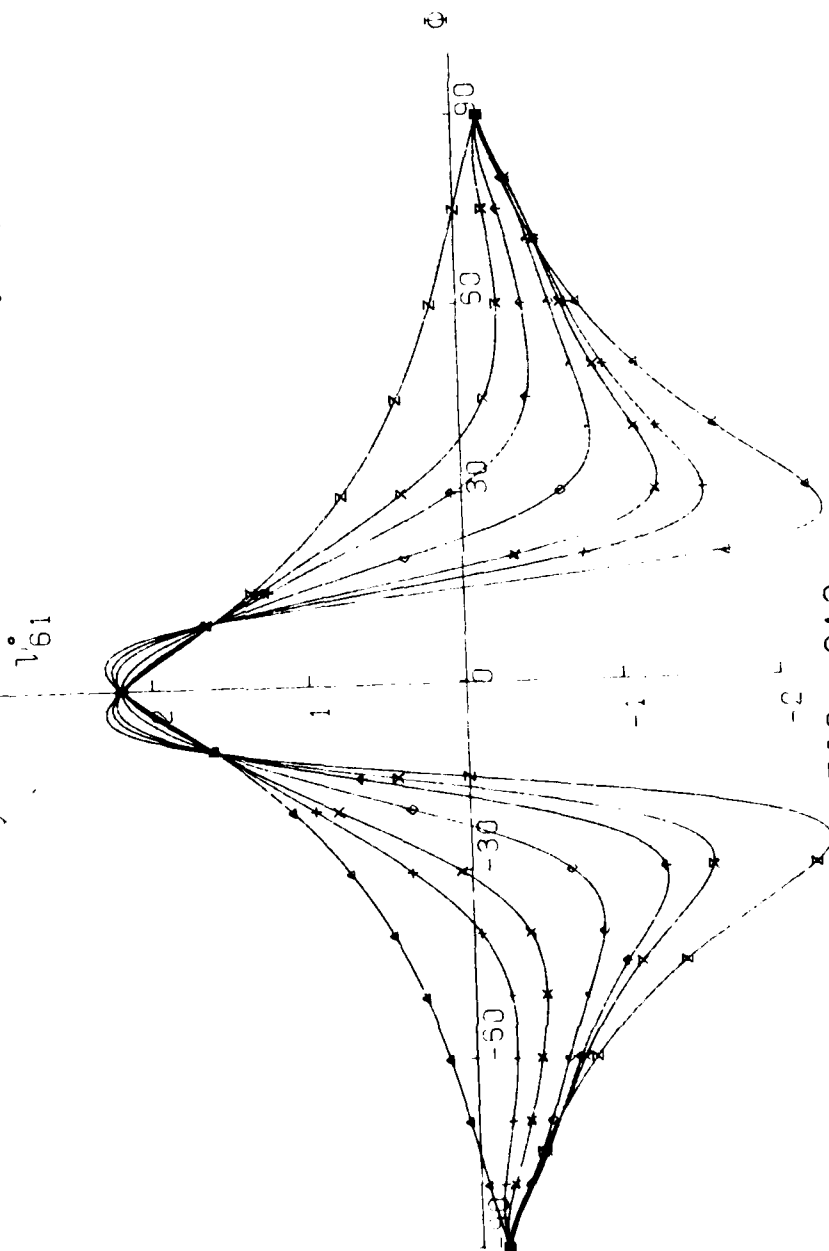
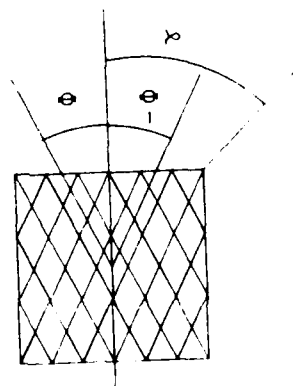


FIG.:213

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\gamma = 0$

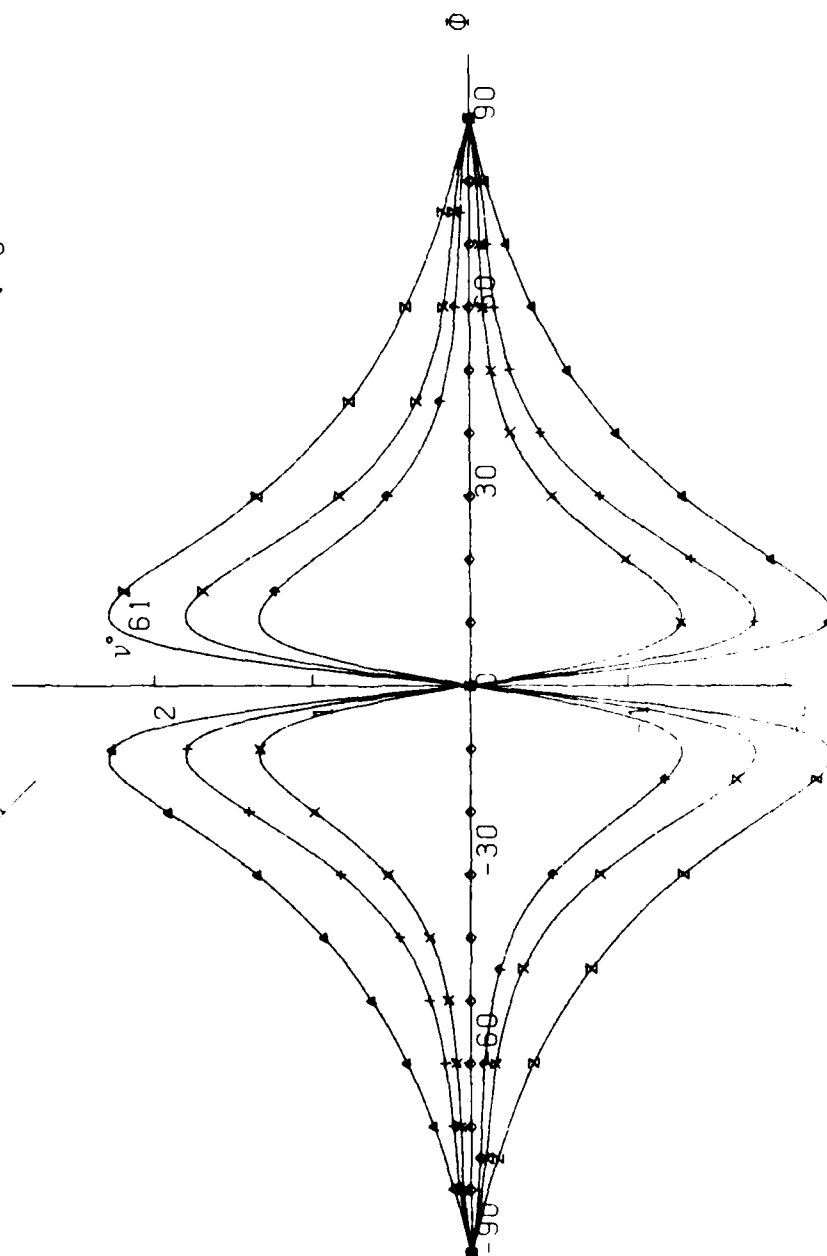
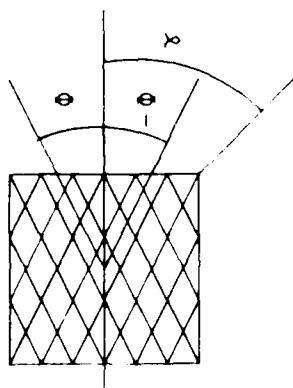
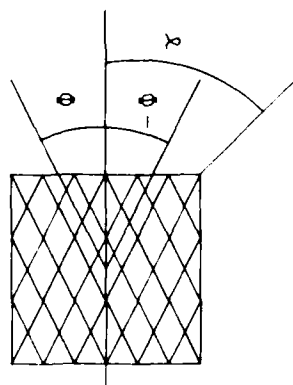


FIG.: 214

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\chi = 15$



v_{61}°

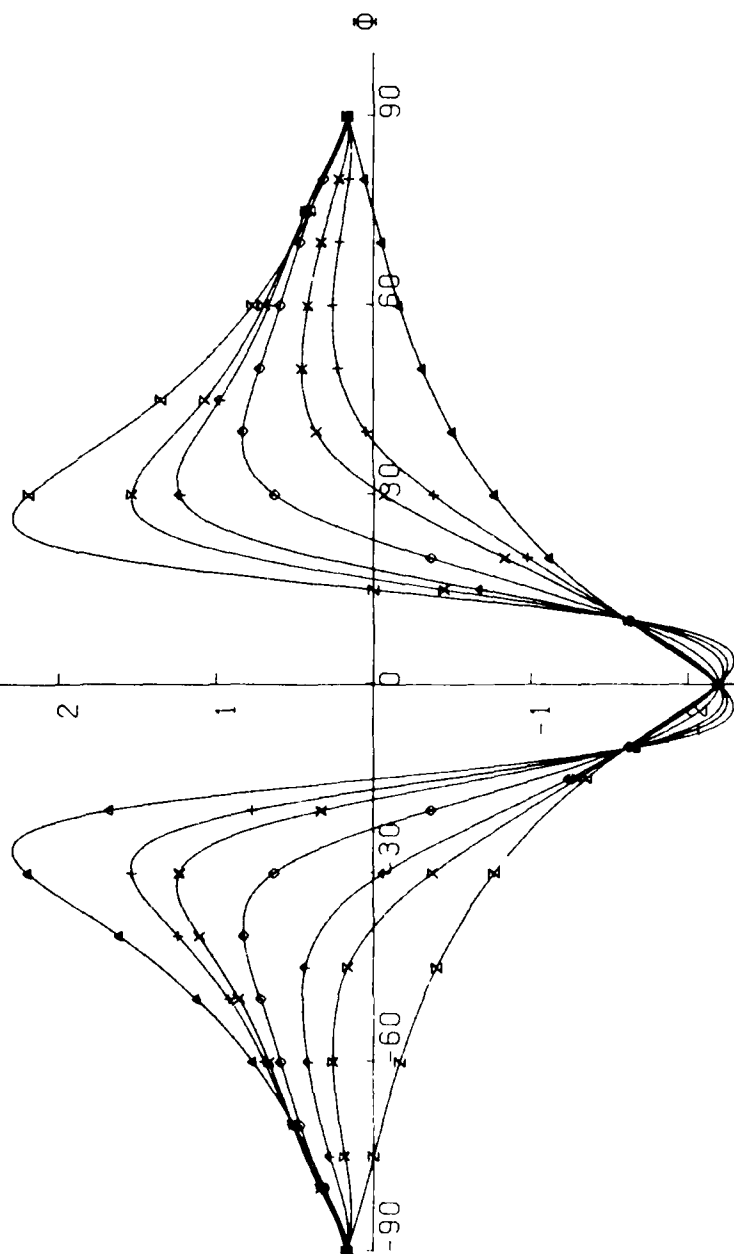
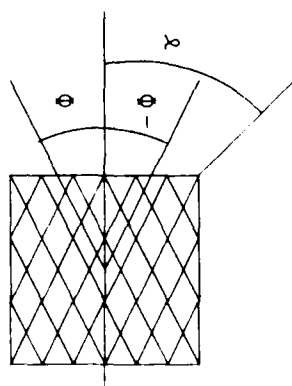


FIG.: 215

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = 30$



ν_{61}°

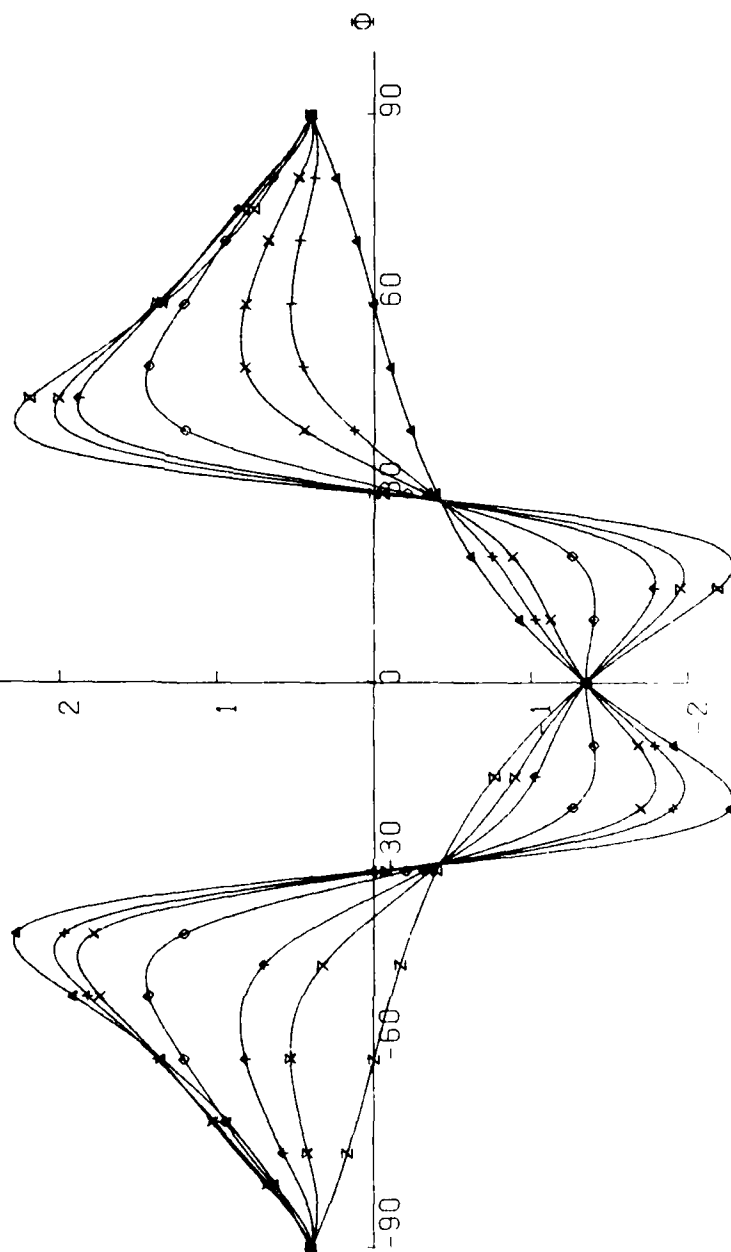
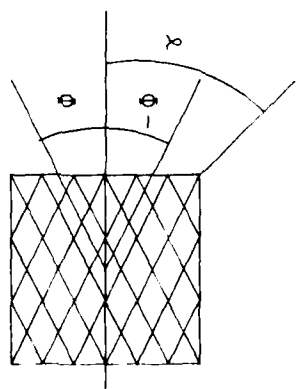


FIG.:216

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \circ (1/1)
 $+$ (1/4)
 \times (1/9)
 Δ (0/1)

$\gamma = 45$



v_{61}^0

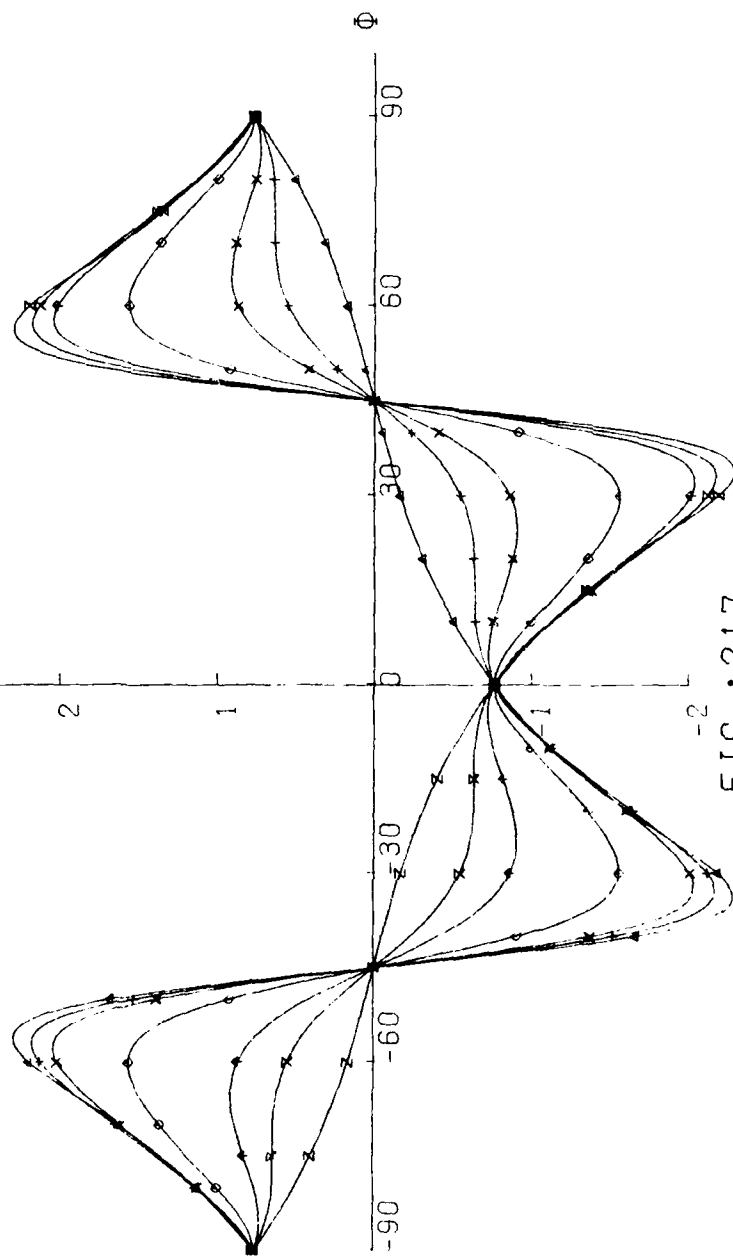


FIG.: 217

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 Σ (1/9)
 Ξ (0/1)

$\gamma = 60$

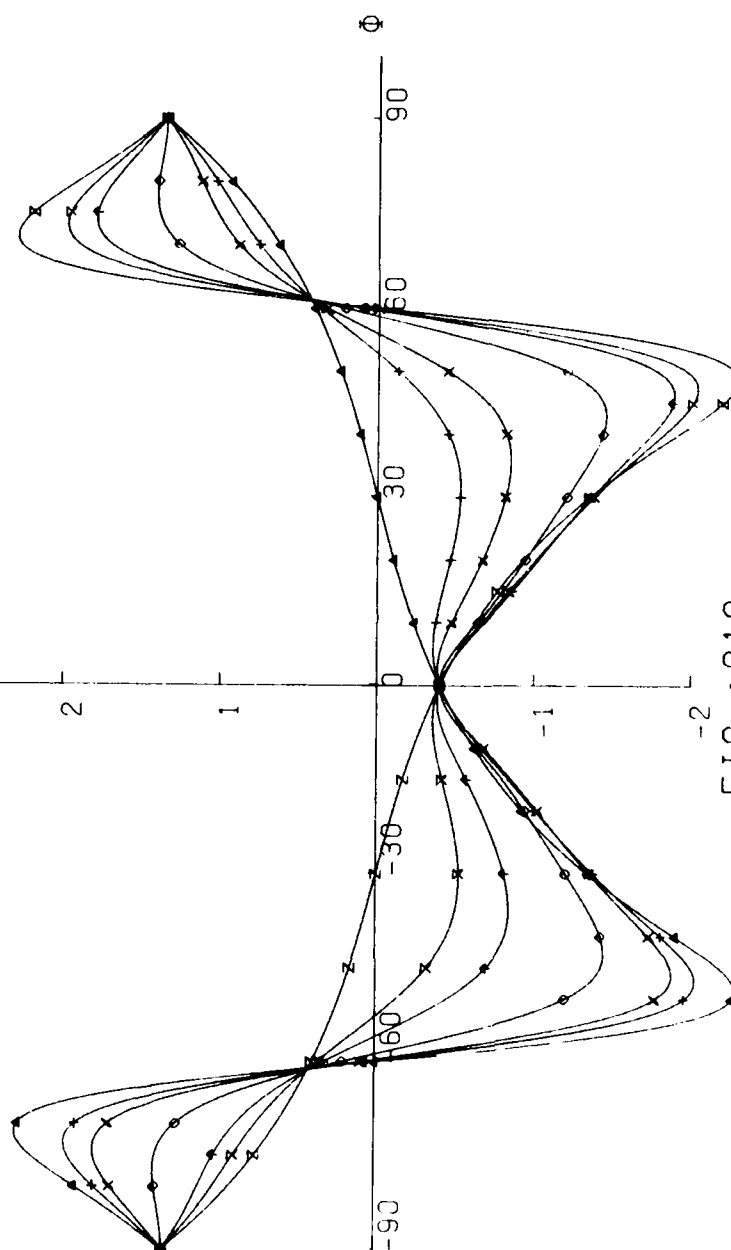
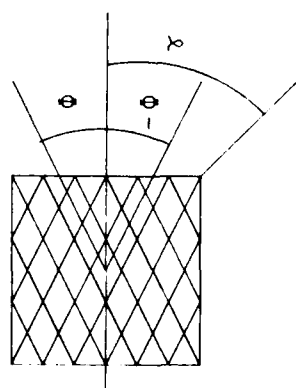


FIG.:218

$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 Σ (1/9)
 Z (0/1)

$\alpha = 75$

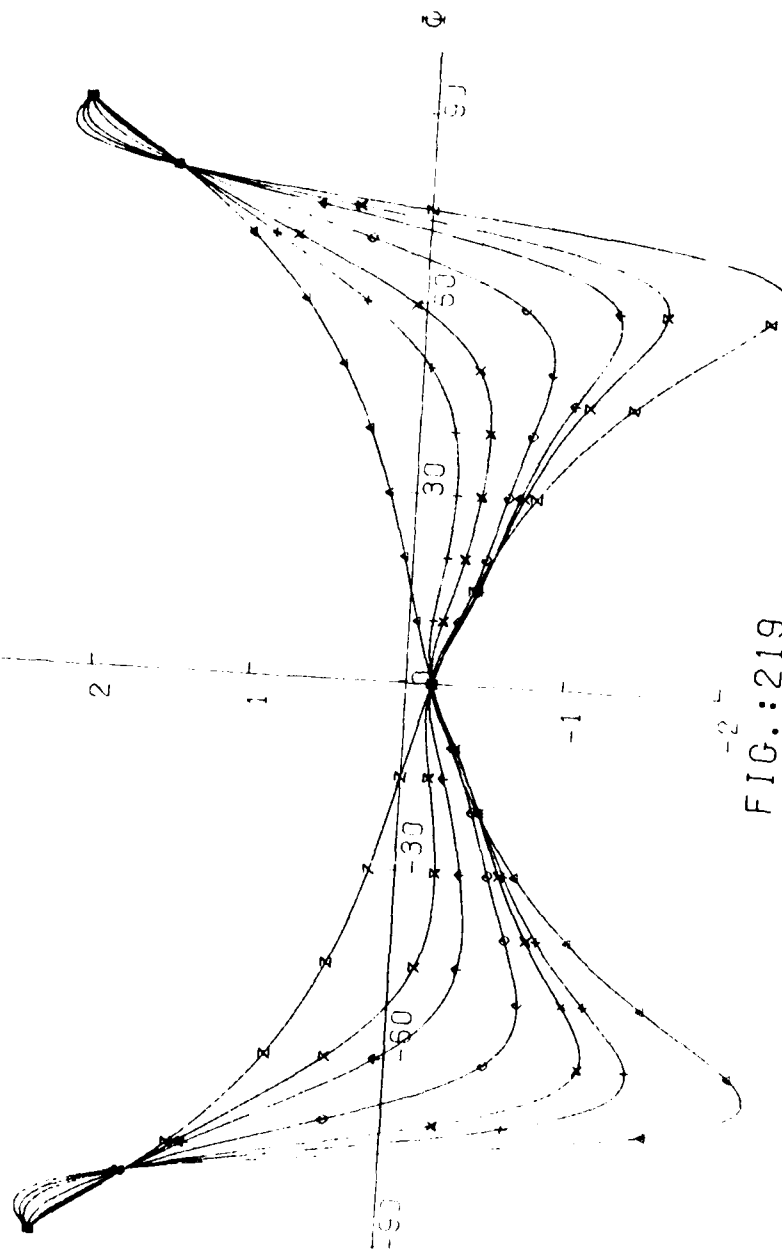
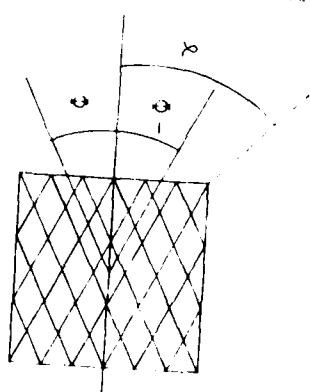


FIG.:219

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\Phi = 15$

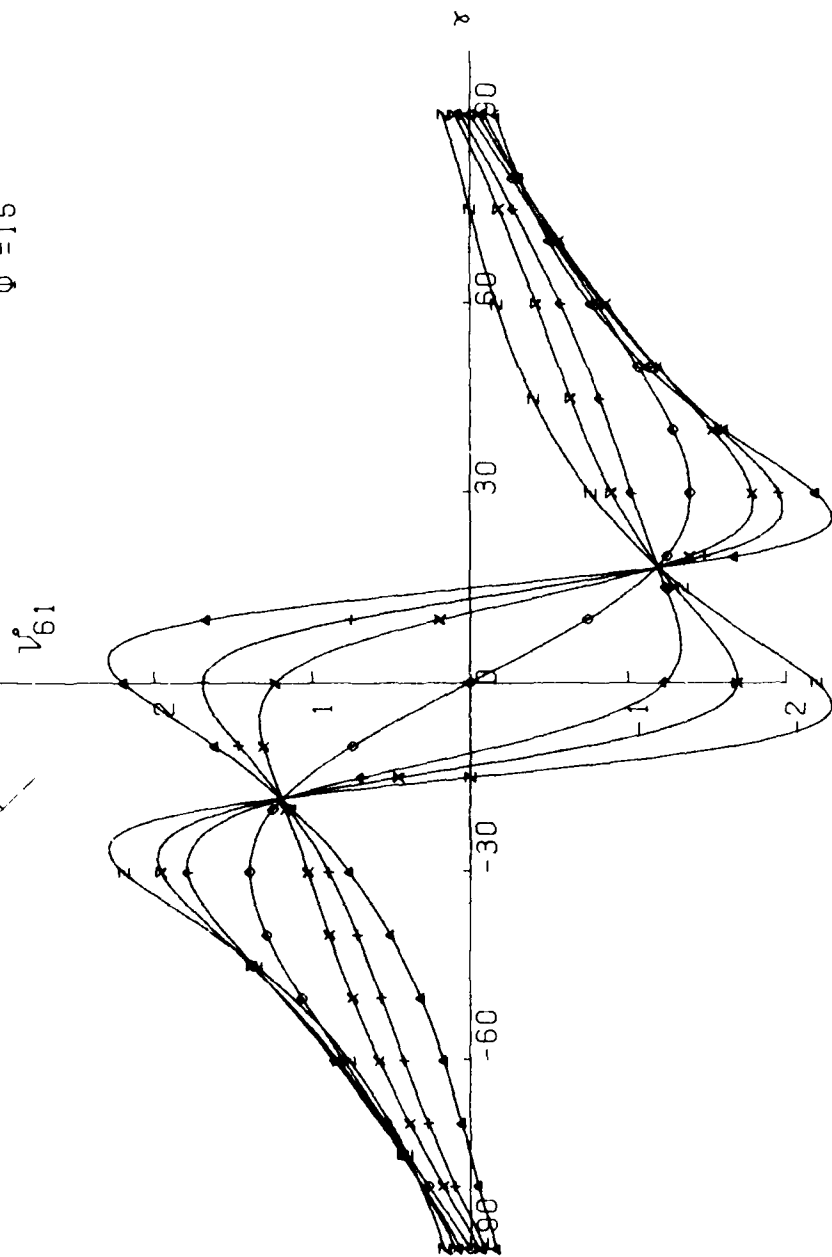
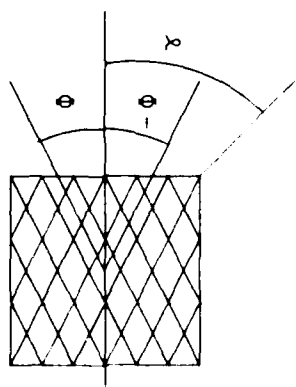
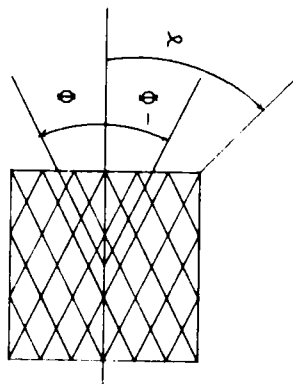


FIG.:220

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\Phi = 30$



v_{61}°

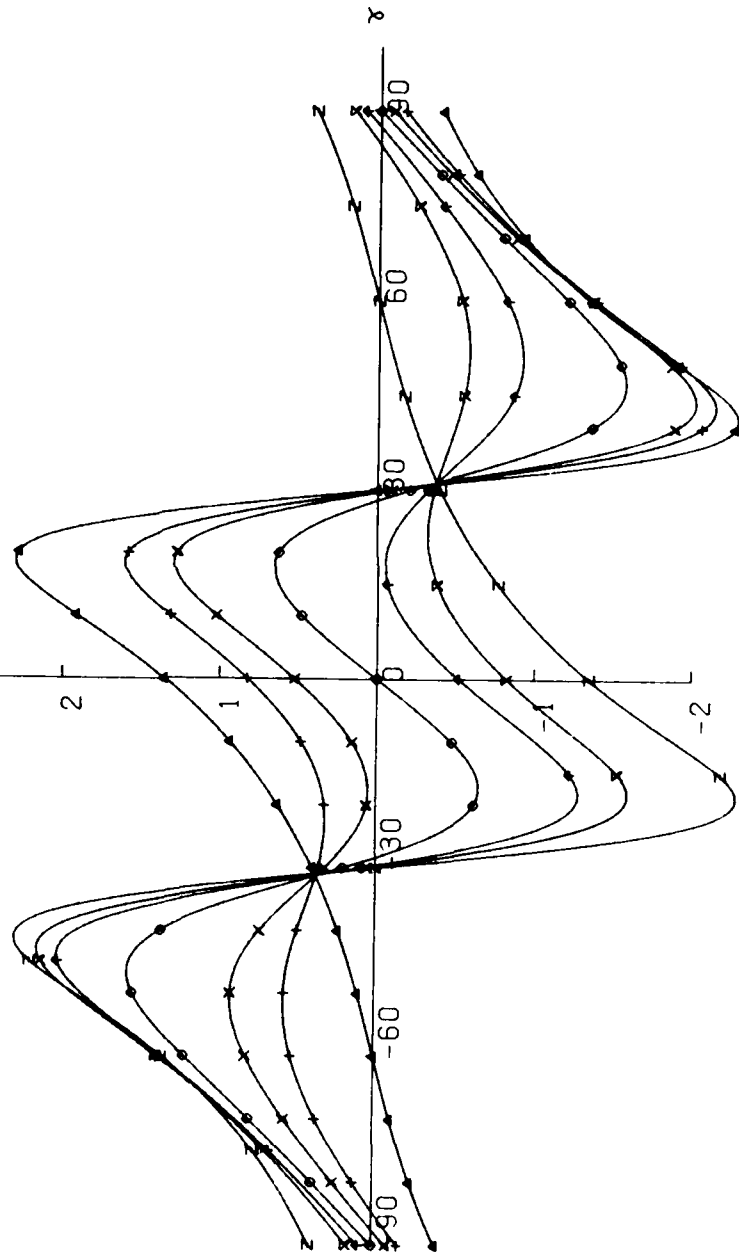


FIG.:221

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\Phi = 45$

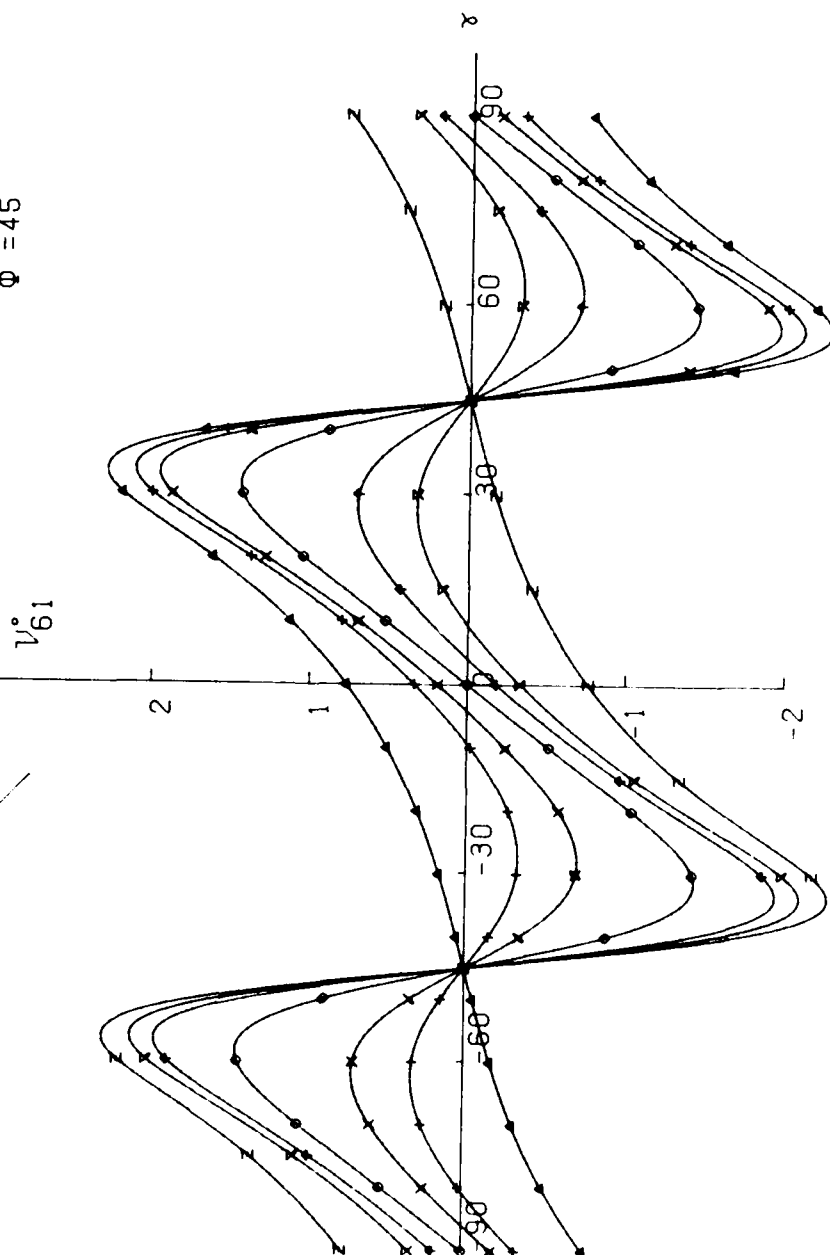
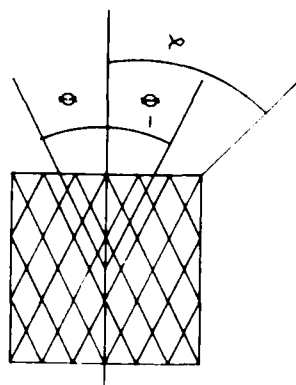
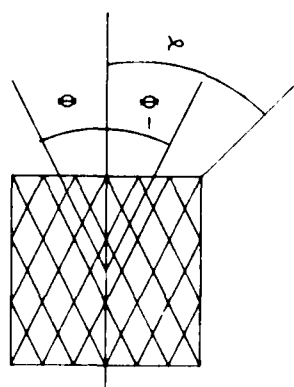


FIG.:222

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\Phi = 60$



ψ_{61}°

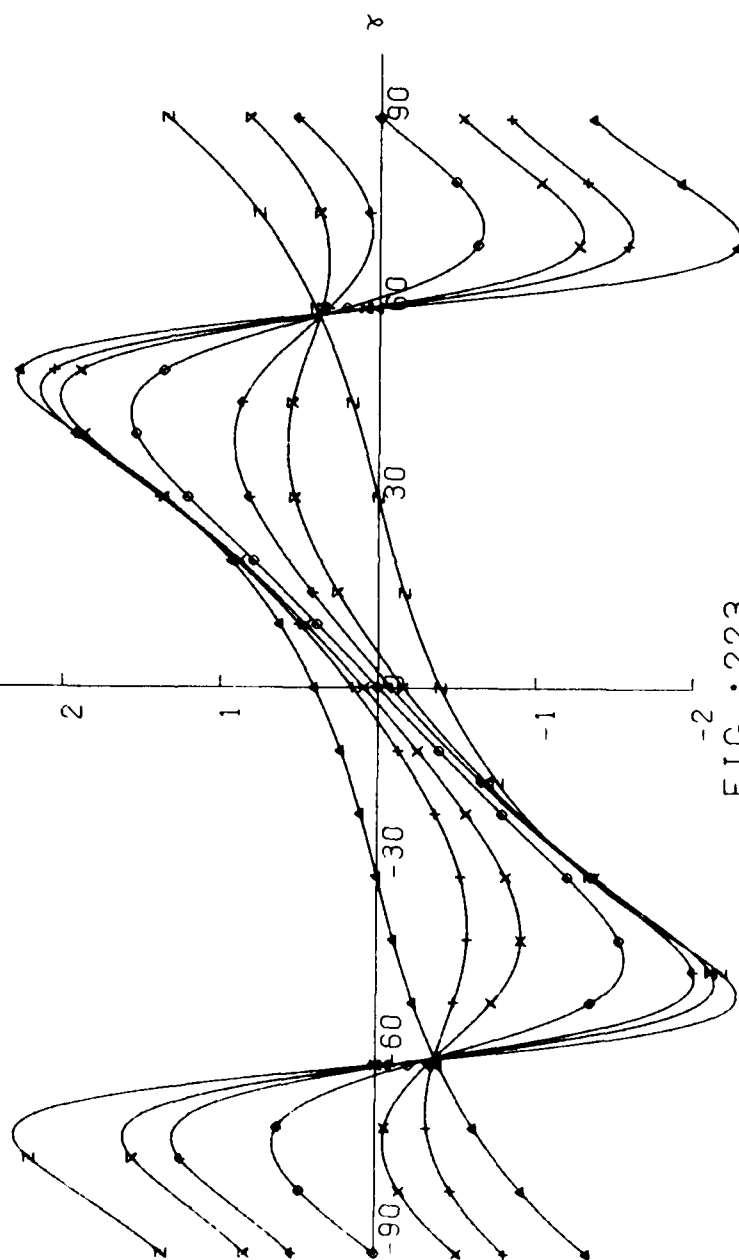
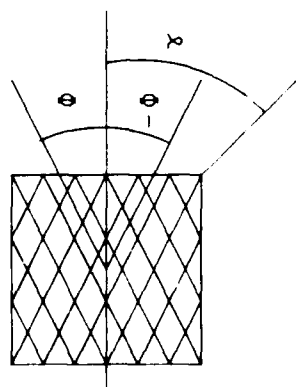


FIG.: 223

$-\phi/\phi$

Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\phi = 75$



ν_{61}

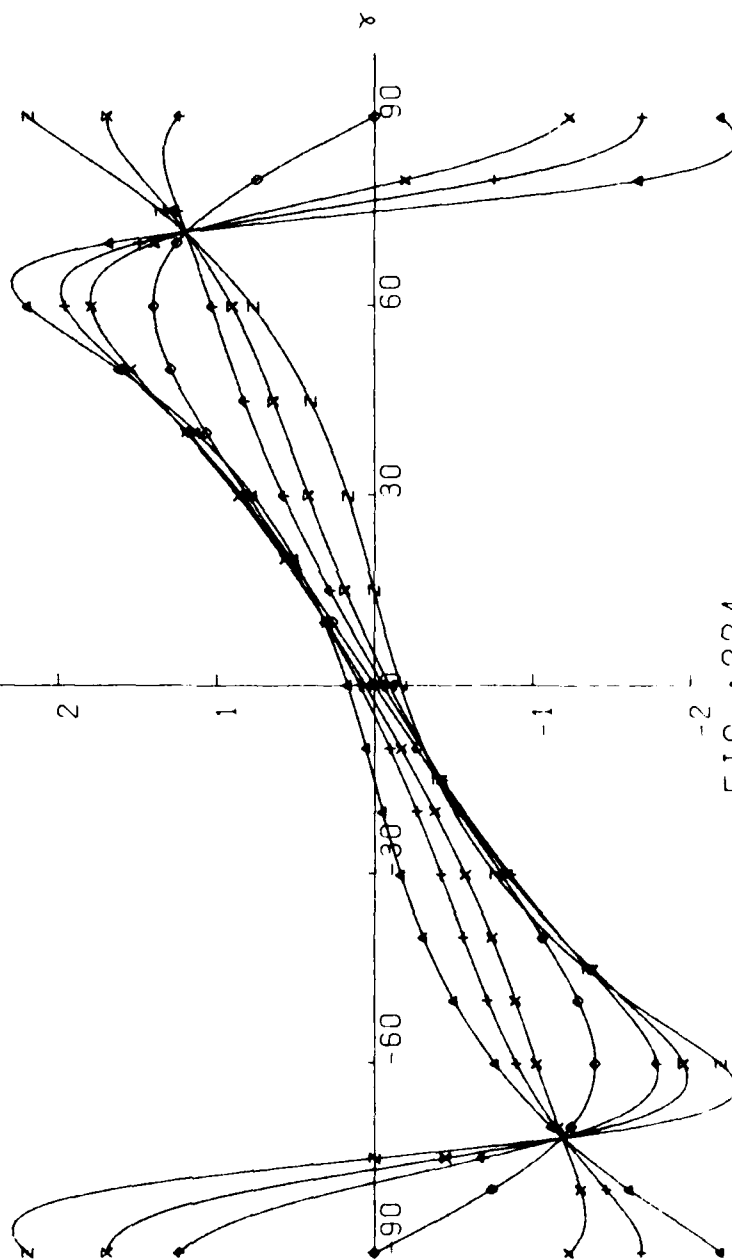


FIG.:224

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 Σ (0/1)

$\chi = -75$

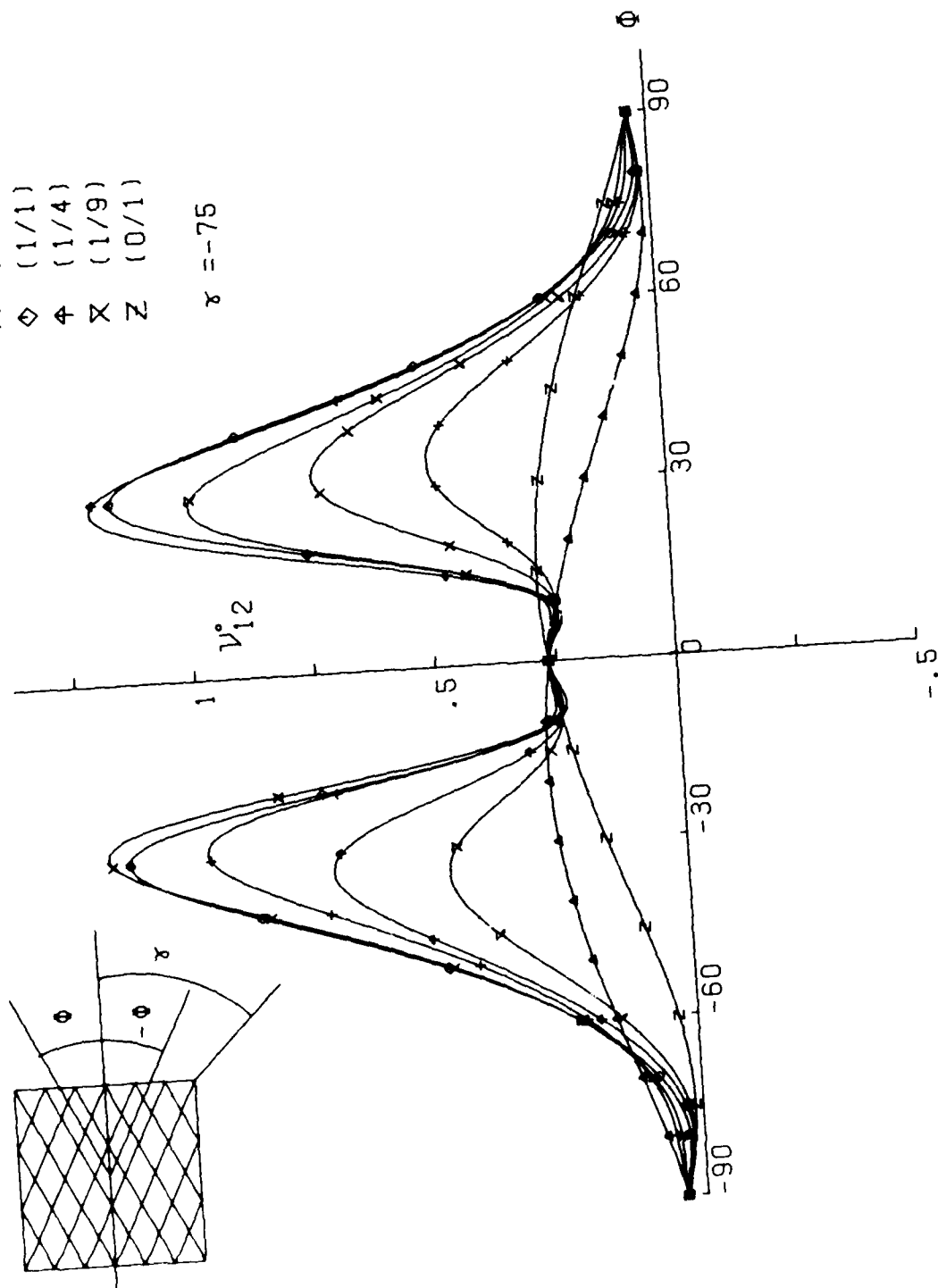
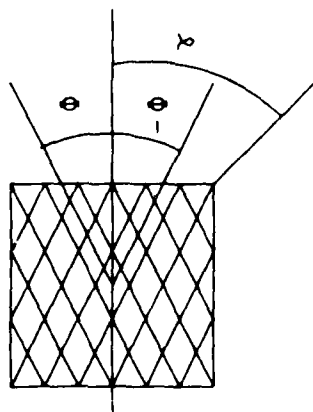


FIG.:225



ϕ/ϕ

Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
∇	(1/4)
\times	(1/9)
z	(0/1)

$\chi = -60$

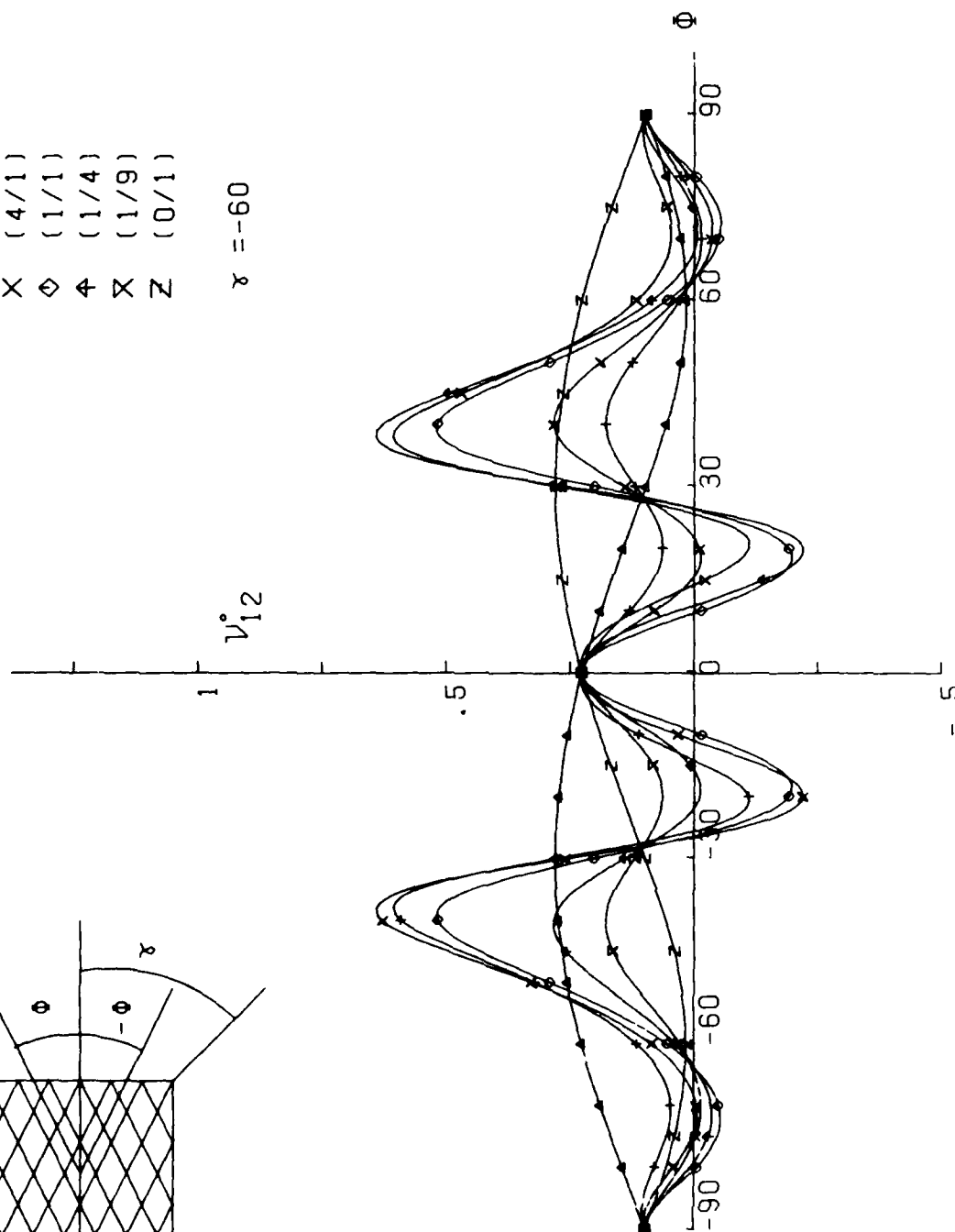
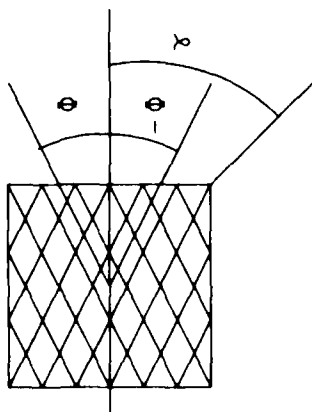


FIG.: 226



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\chi = -45$

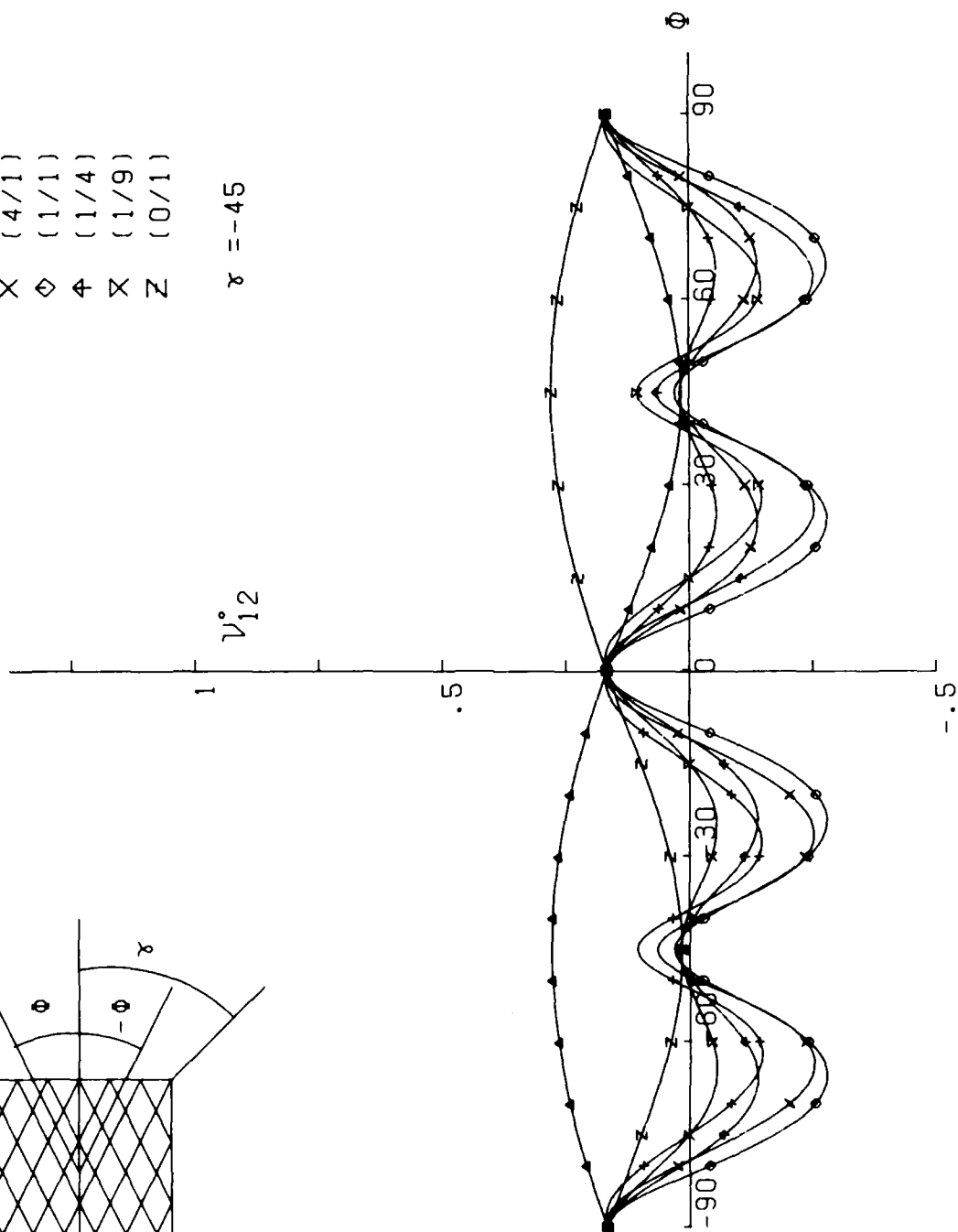
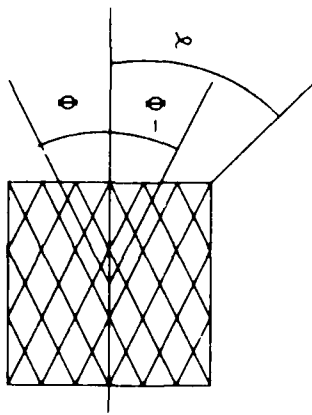


FIG.:227



Φ/Φ

Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
4	(1/4)
Σ	(1/9)
Z	(0/1)

$\chi = -30$

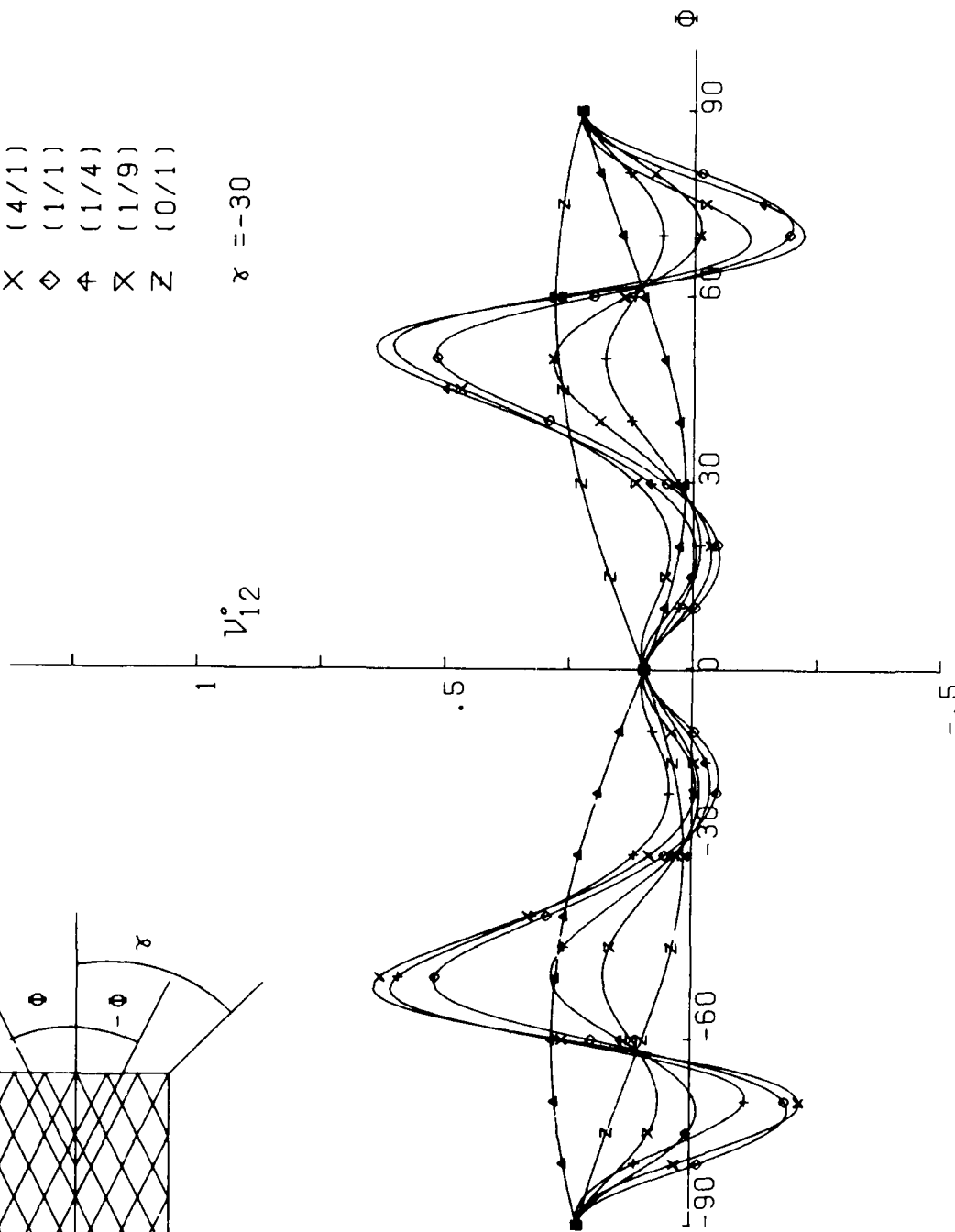


FIG.:228

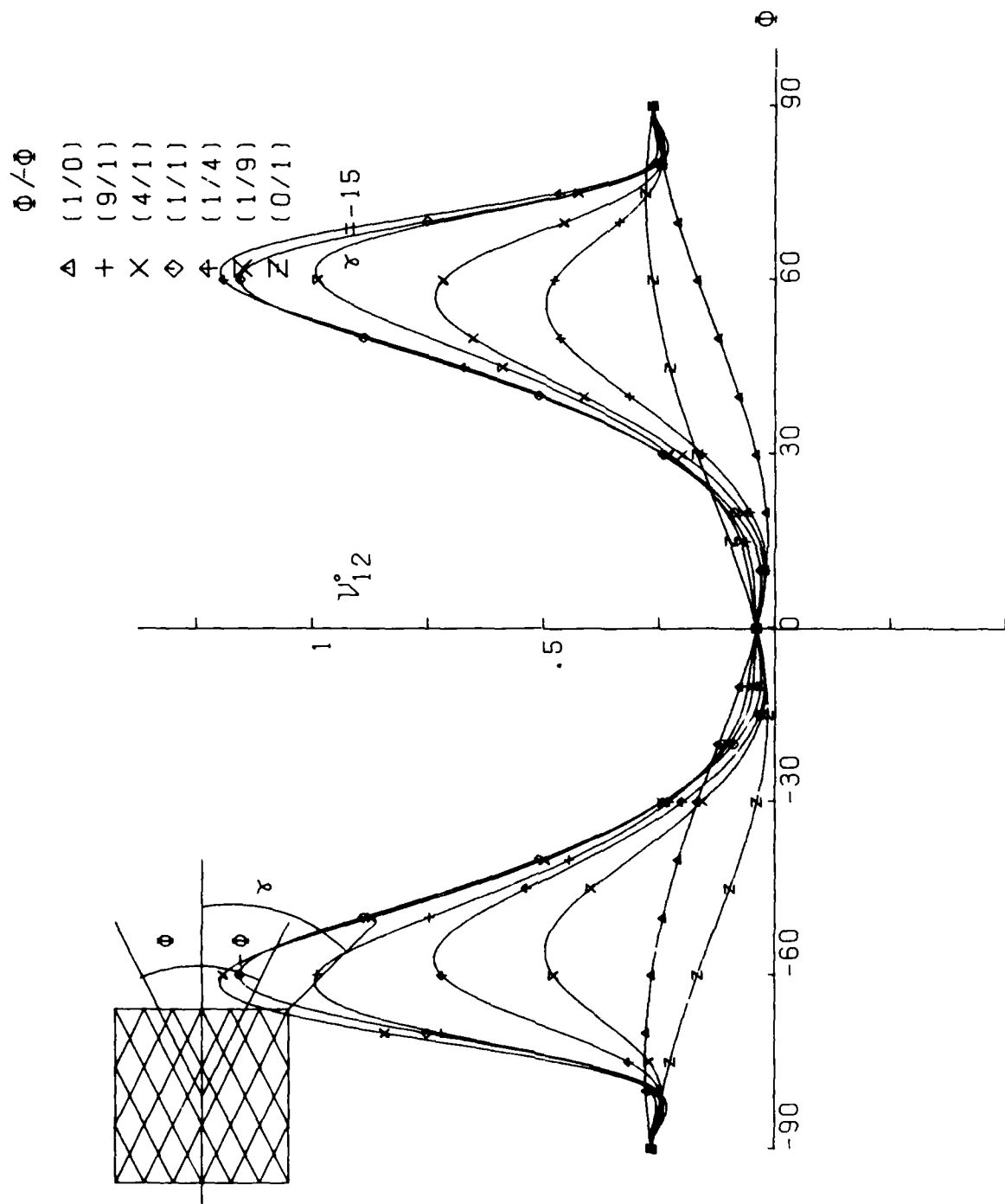


FIG.:229

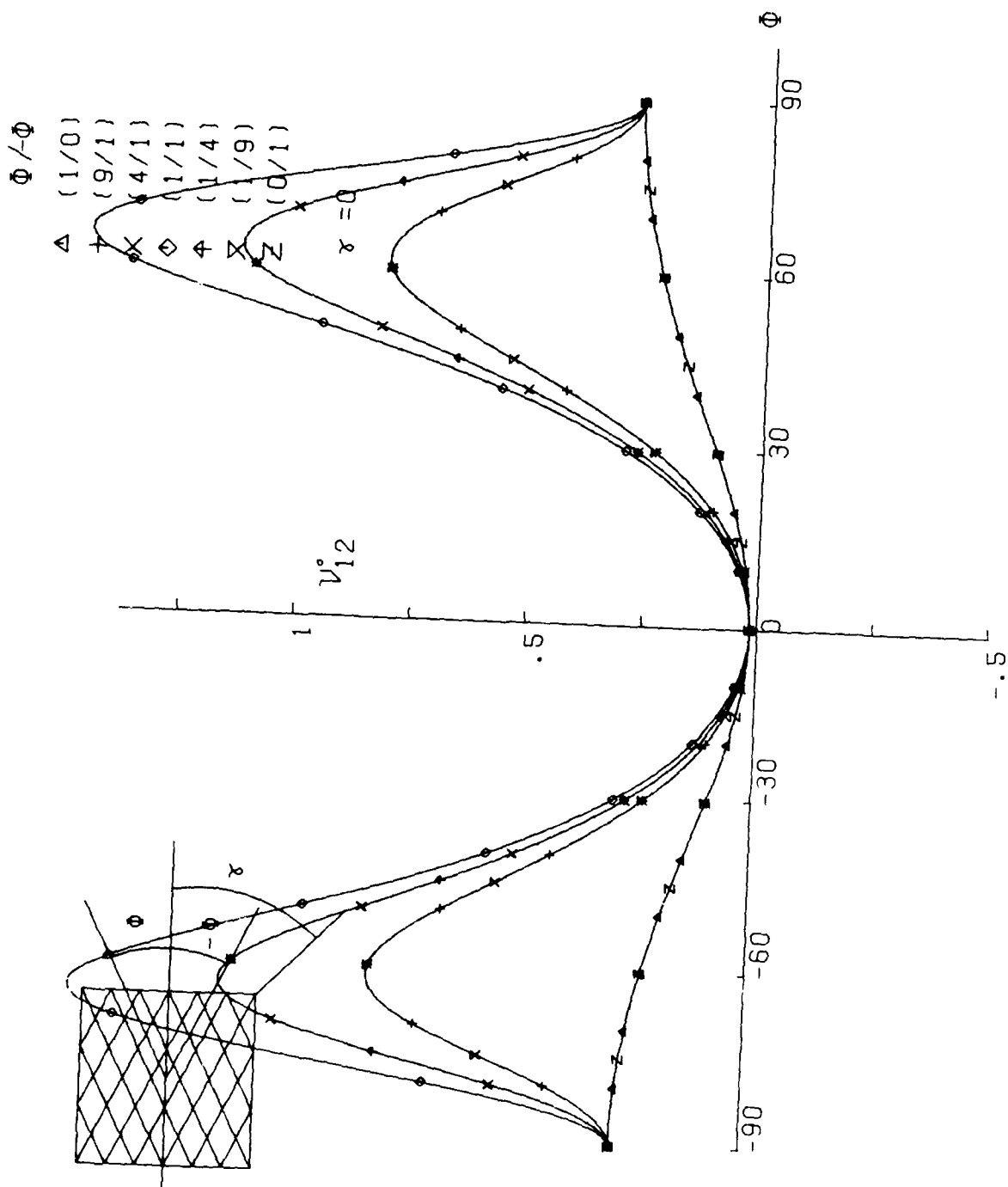


FIG.: 230

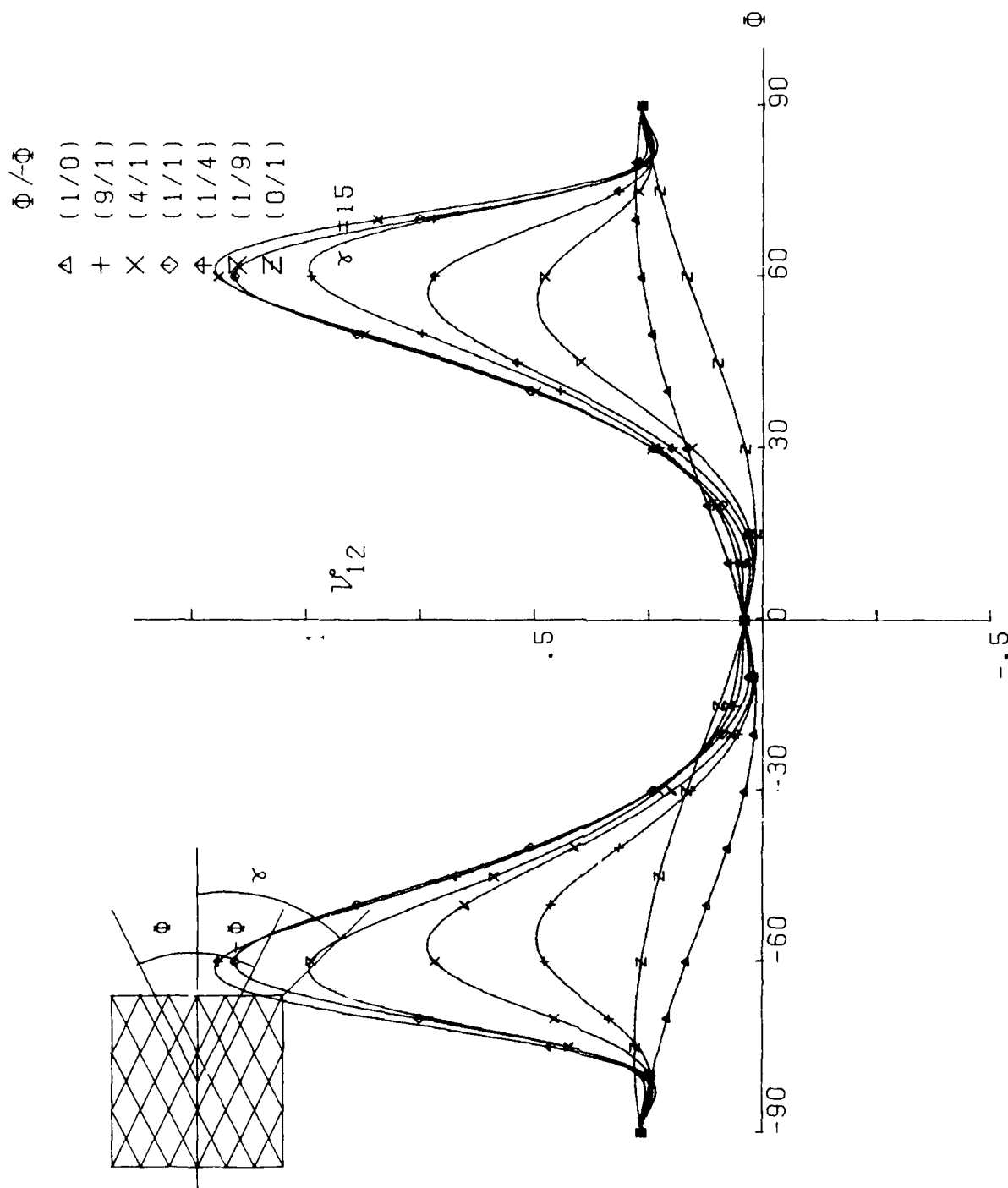
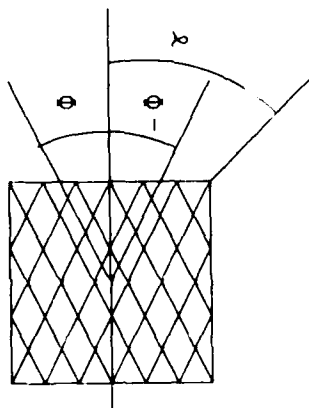


FIG.:231



$\Phi / -\Phi$

Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
\oplus	(1/4)
\times	(1/9)
Z	(0/1)

$\chi = 30$

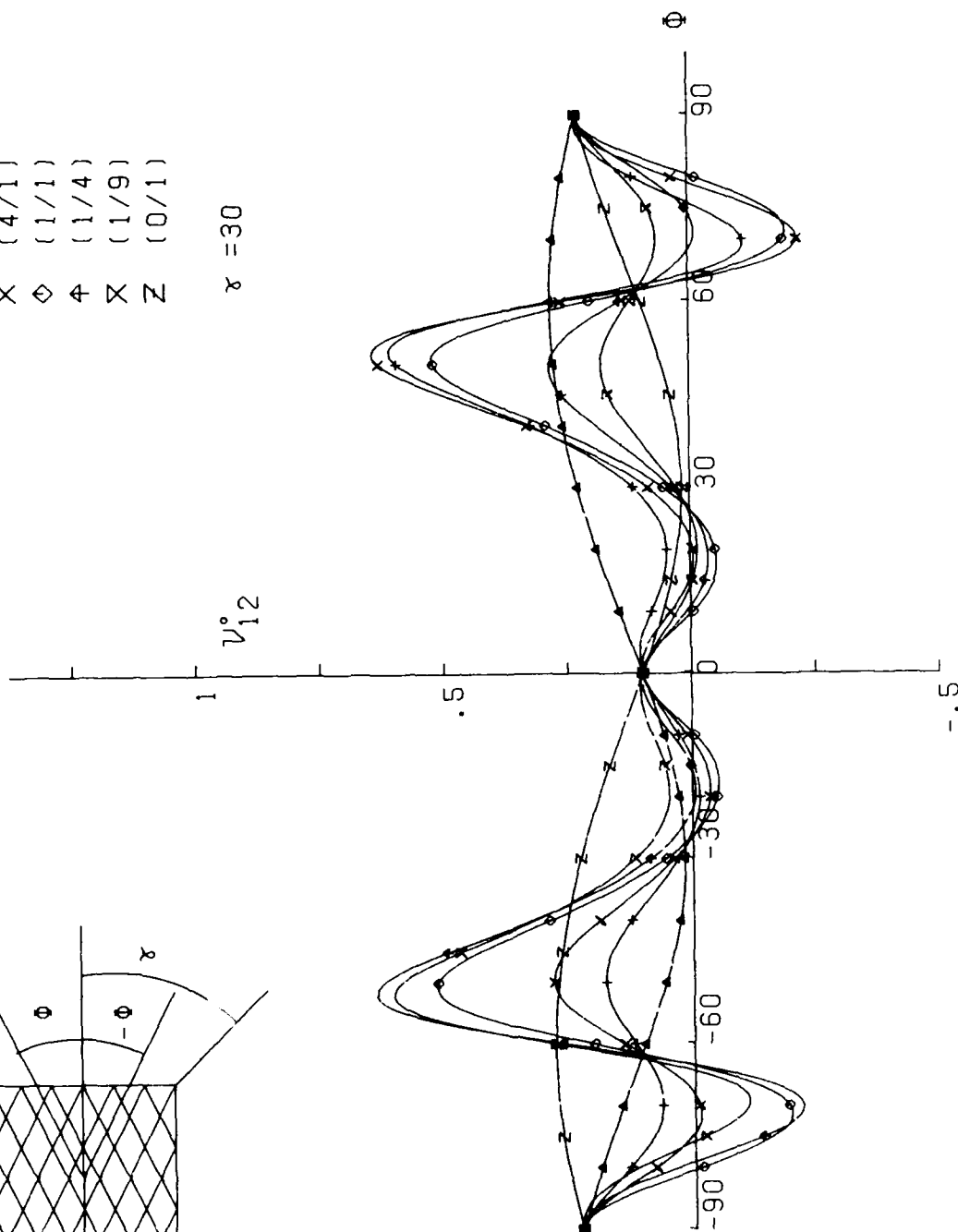
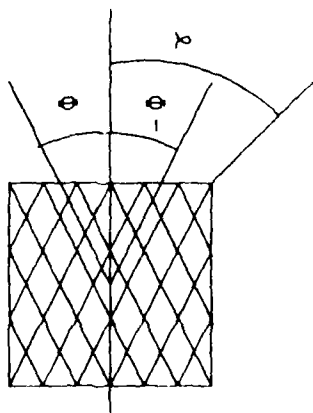


FIG.: 232



$\Phi / -\Phi$

Δ	(1/0)
+	(9/1)
\times	(4/1)
\diamond	(1/1)
\oplus	(1/4)
\otimes	(1/9)
Σ	(0/1)

$\gamma = 45$

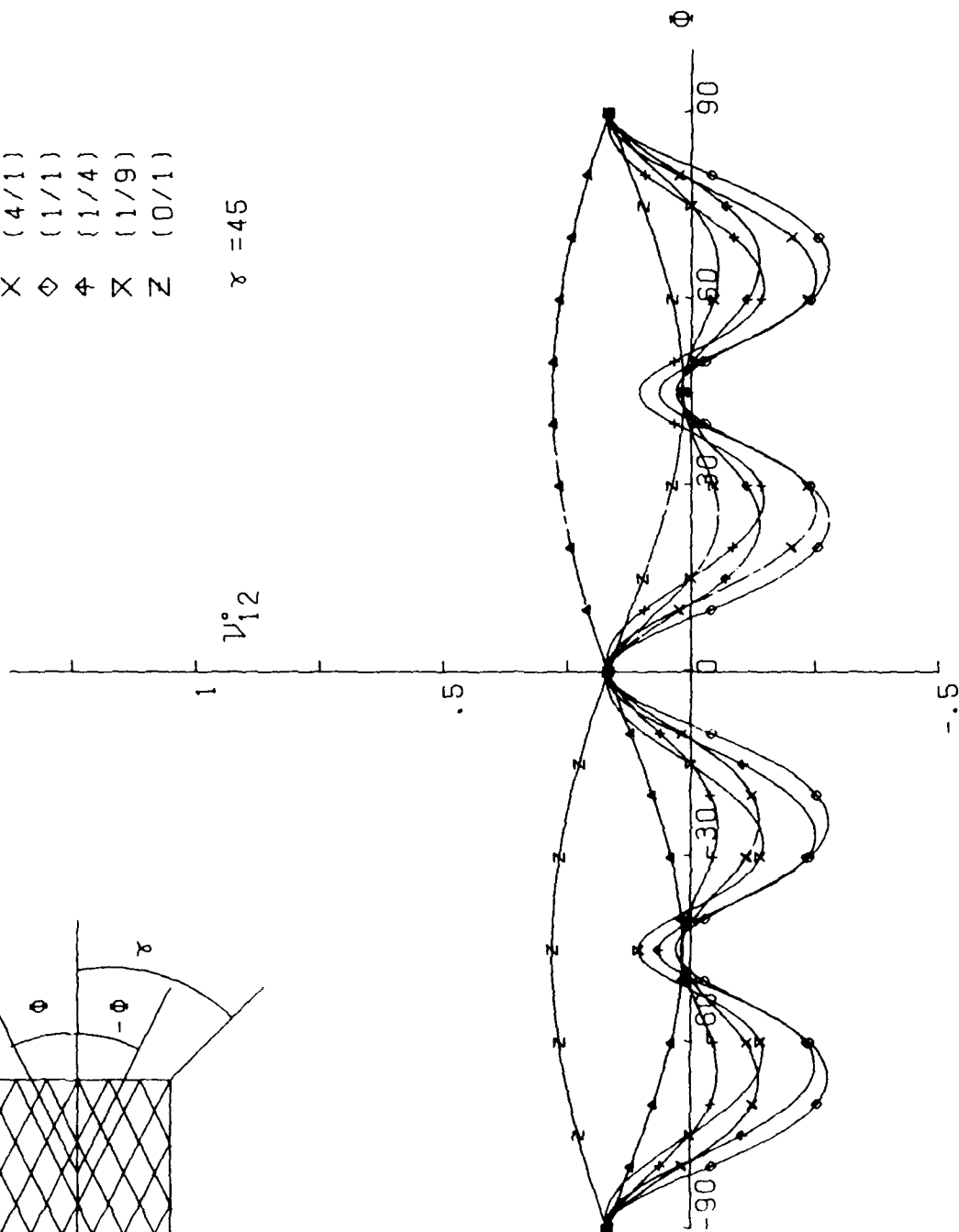
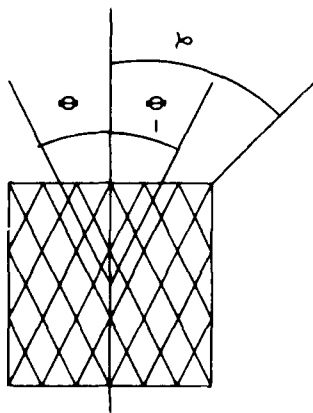


FIG.: 233



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\chi = 60$

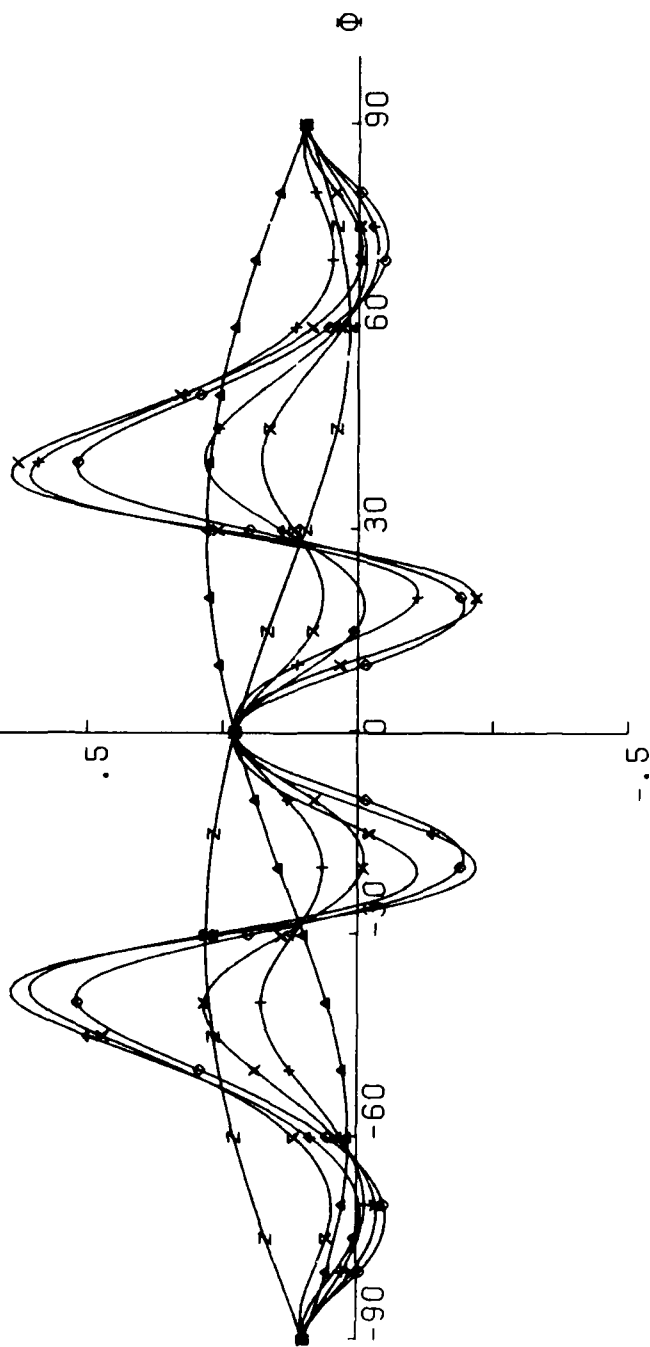


FIG.: 234

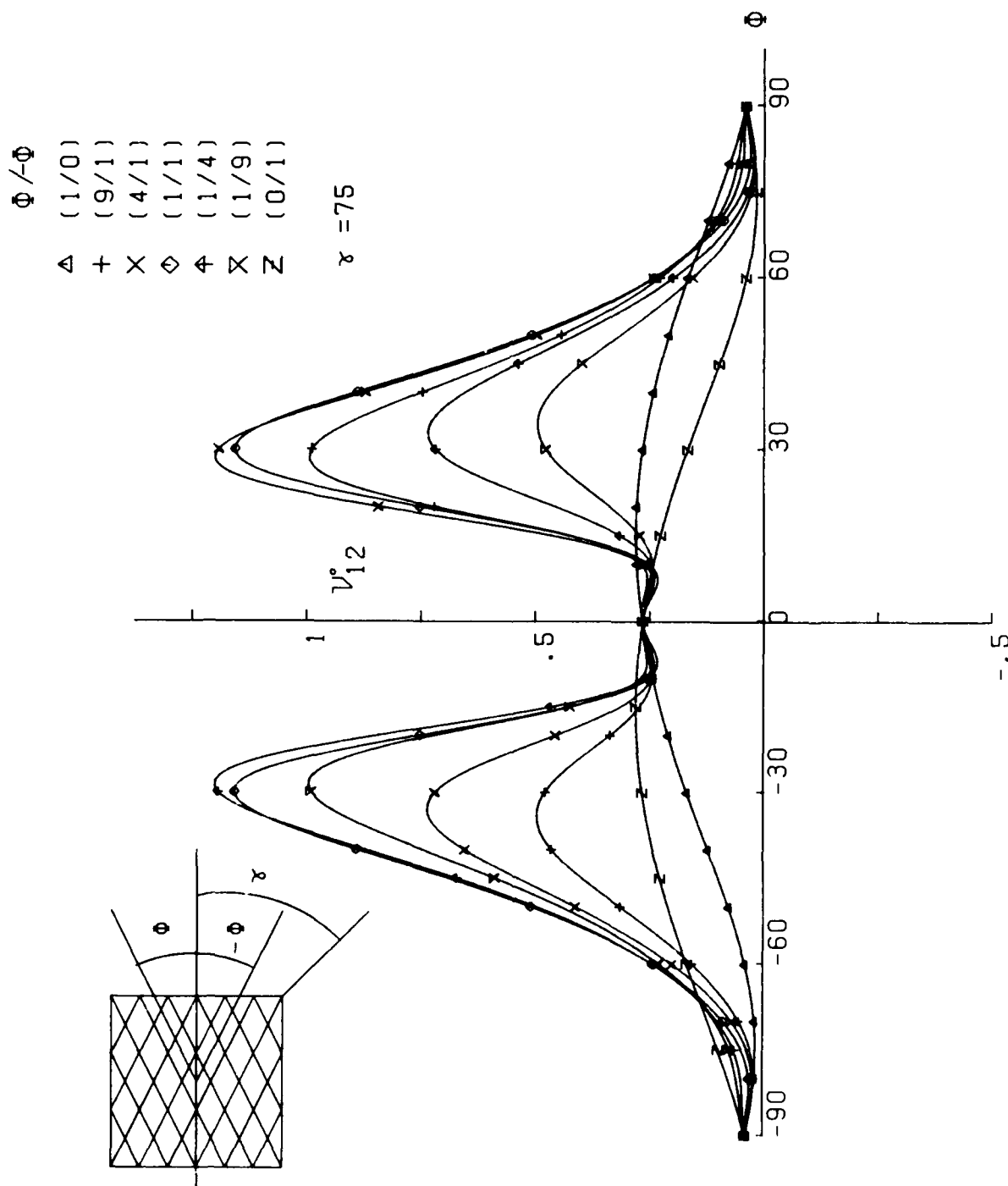


FIG.:235

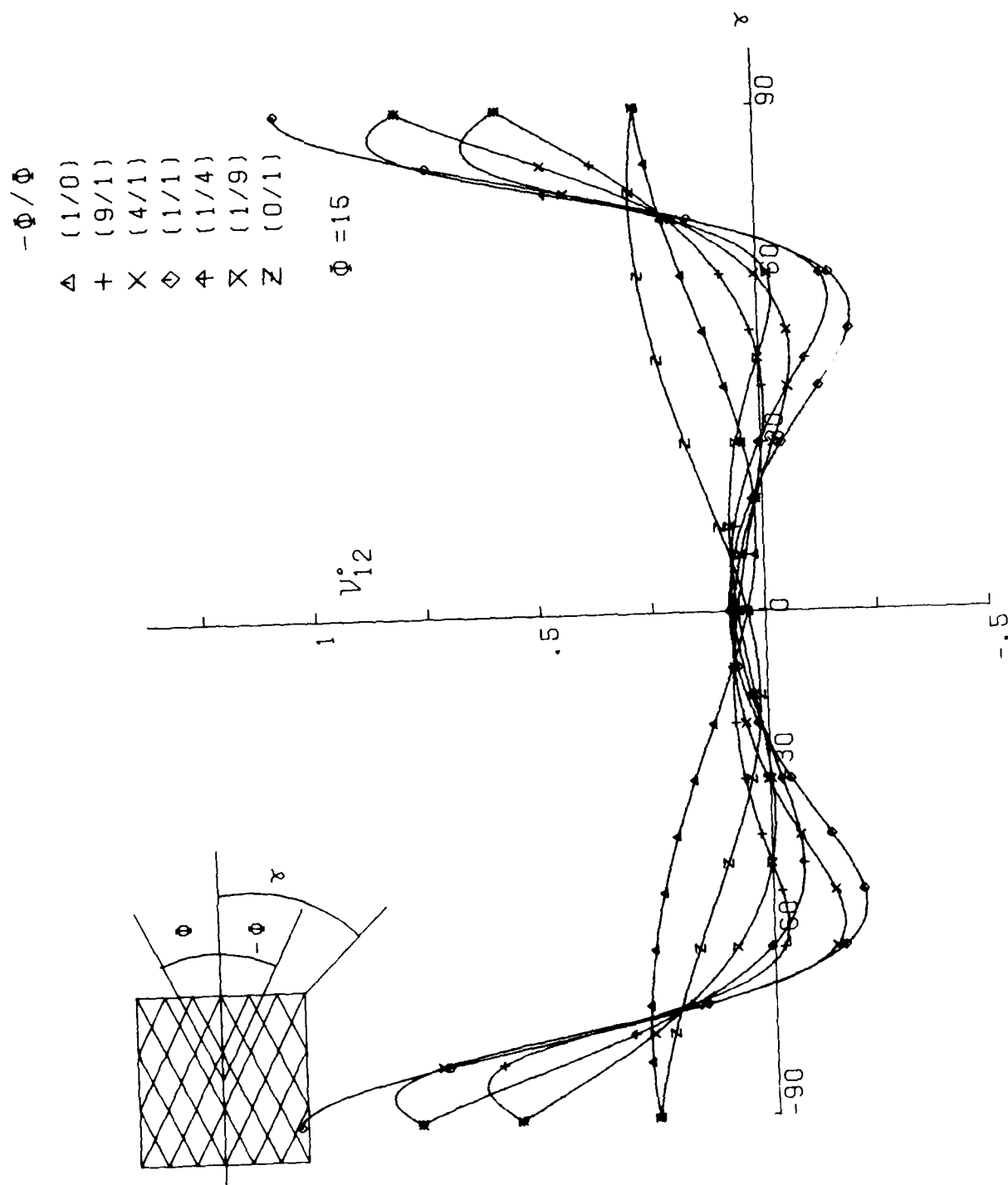


FIG.: 236

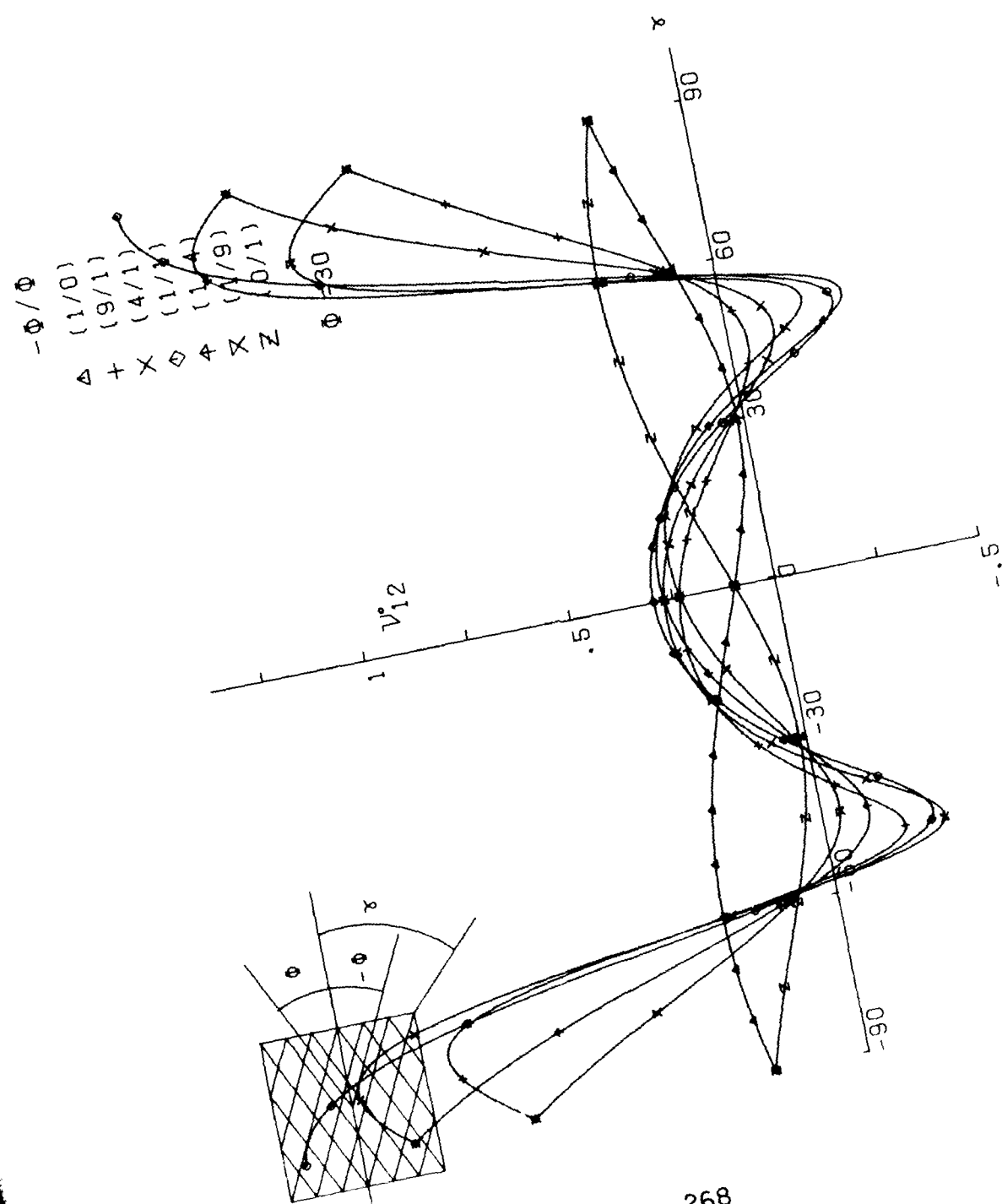
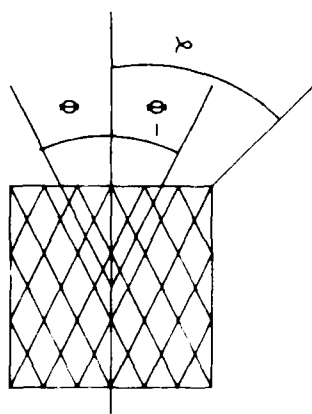


FIG. 237



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 Σ (1/9)
 Z (0/1)

$\Phi = 45$

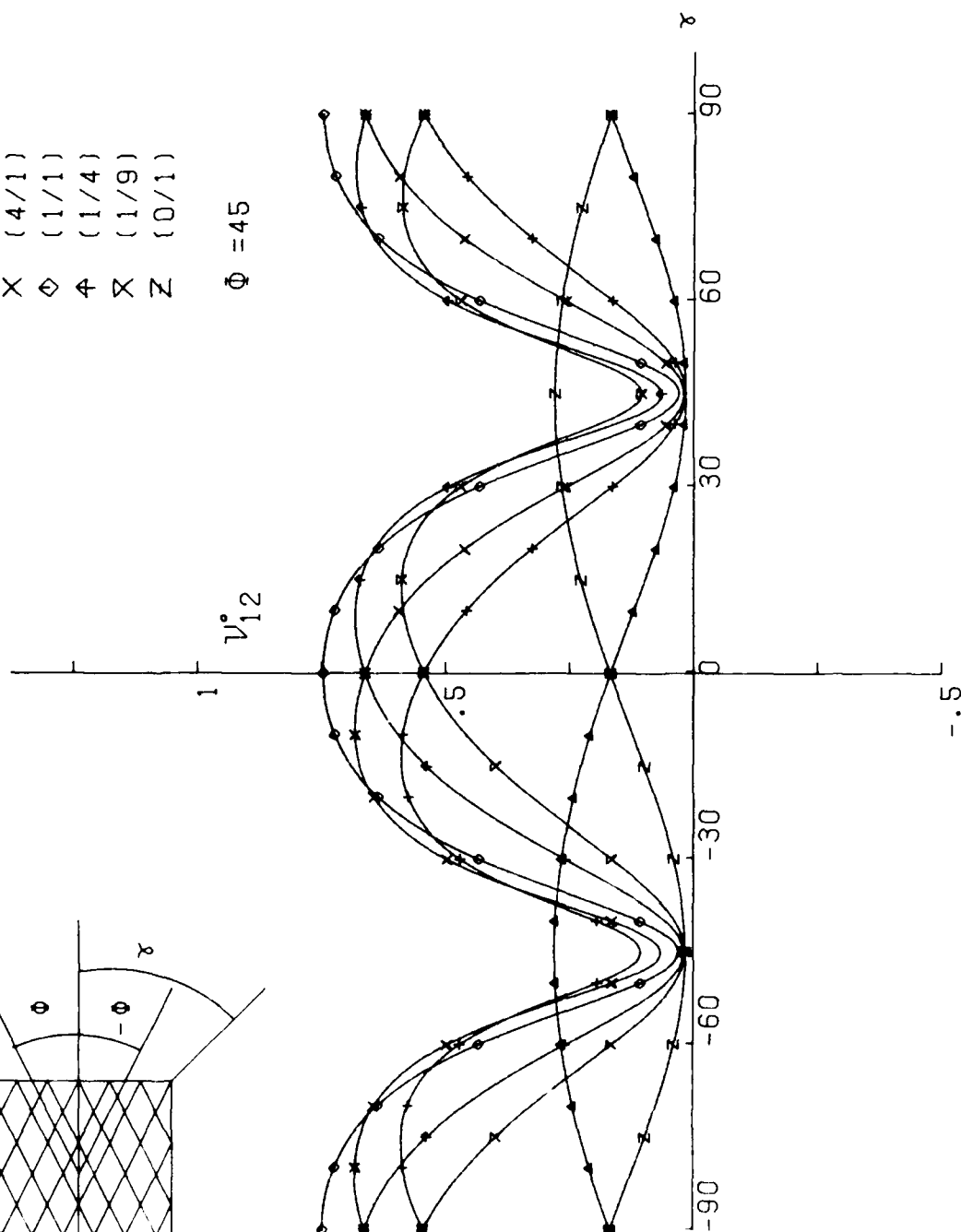
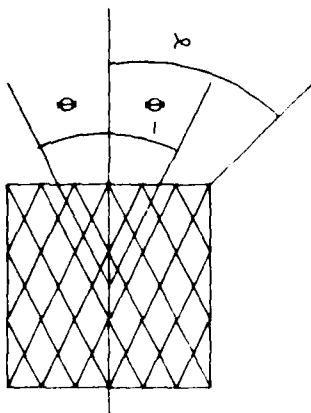


FIG.: 238



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\phi = 60$

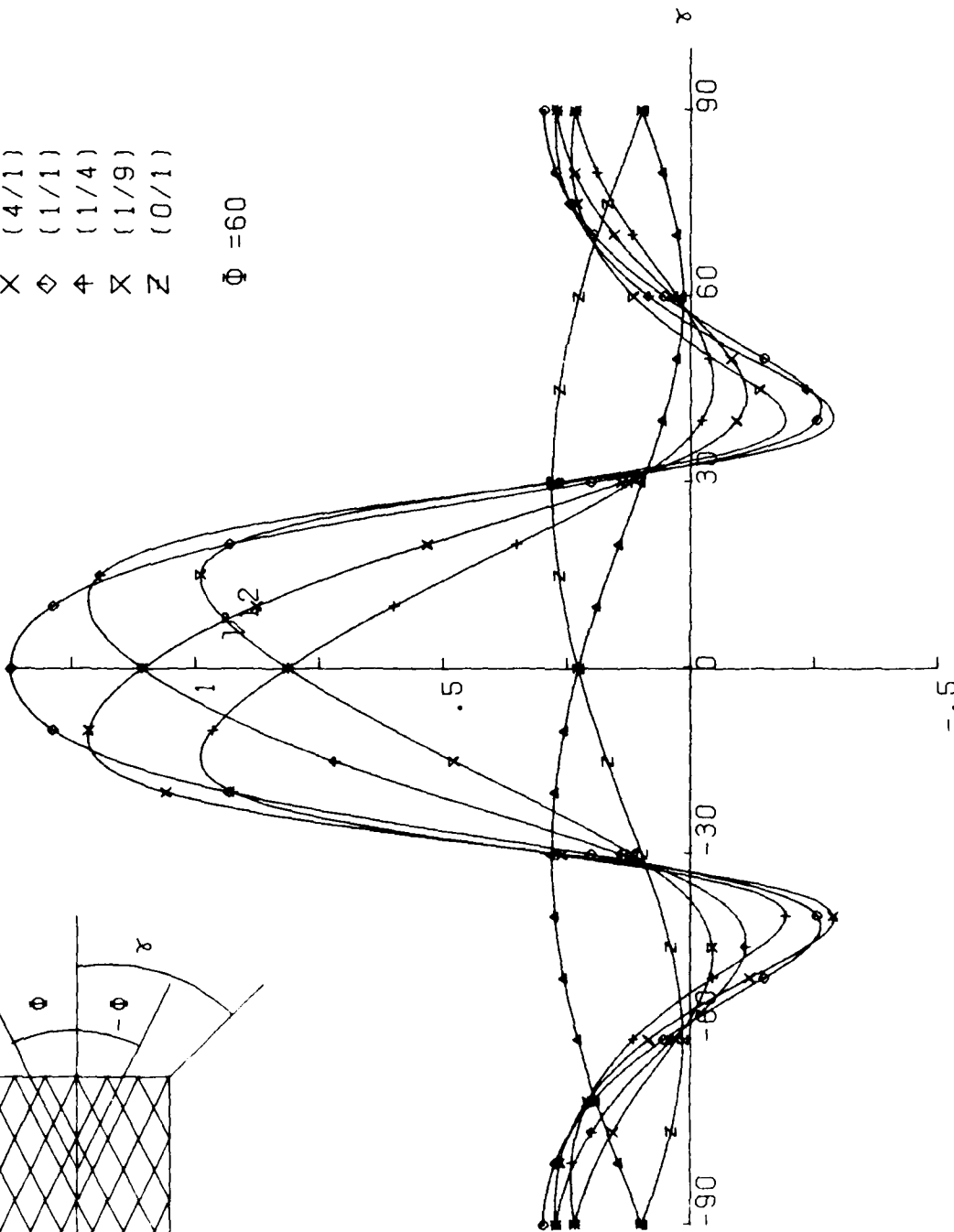


FIG.:239

$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 Σ (1/9)
 Z (0/1)
 $\phi = 75^\circ$

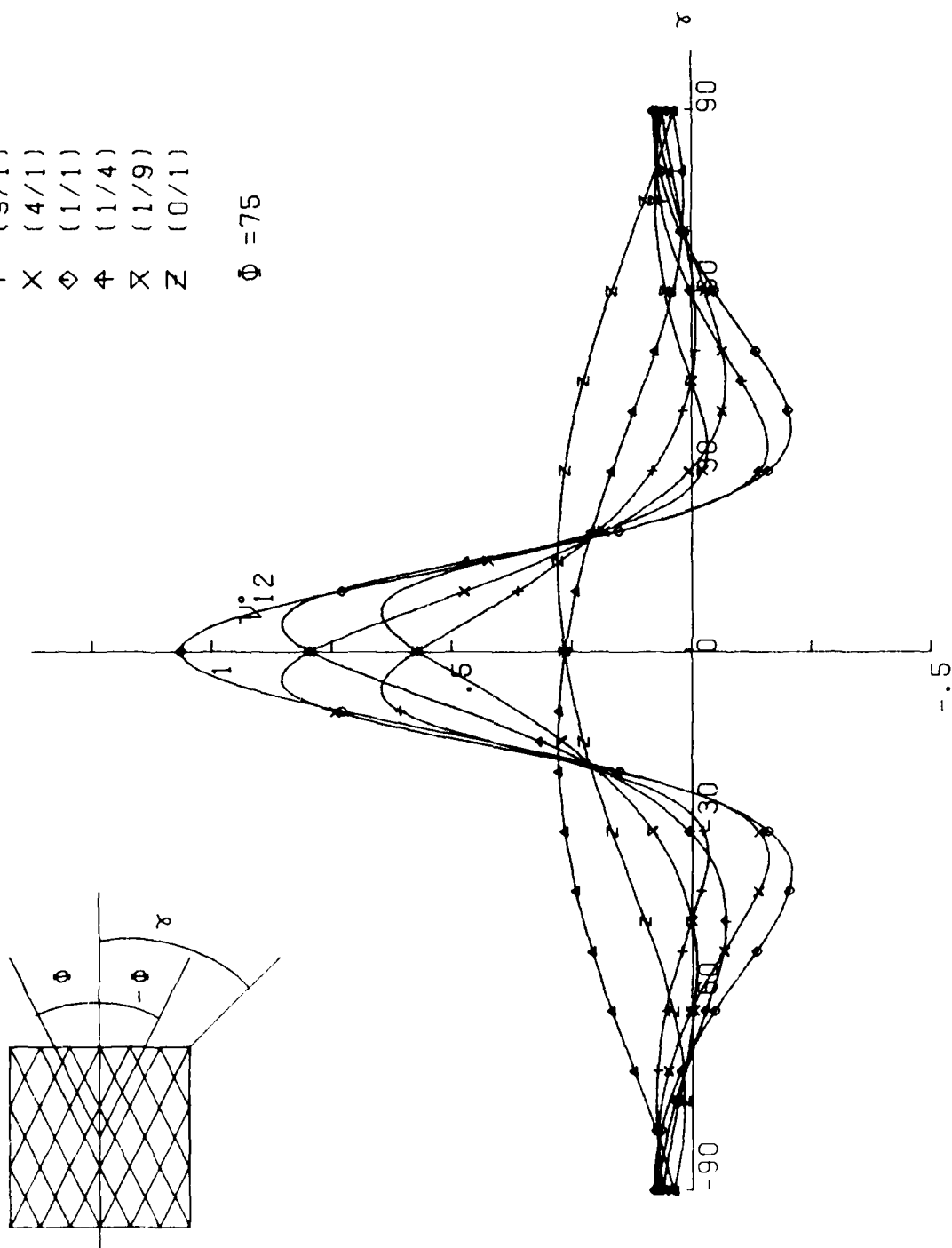


FIG.:240

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\chi = -75$

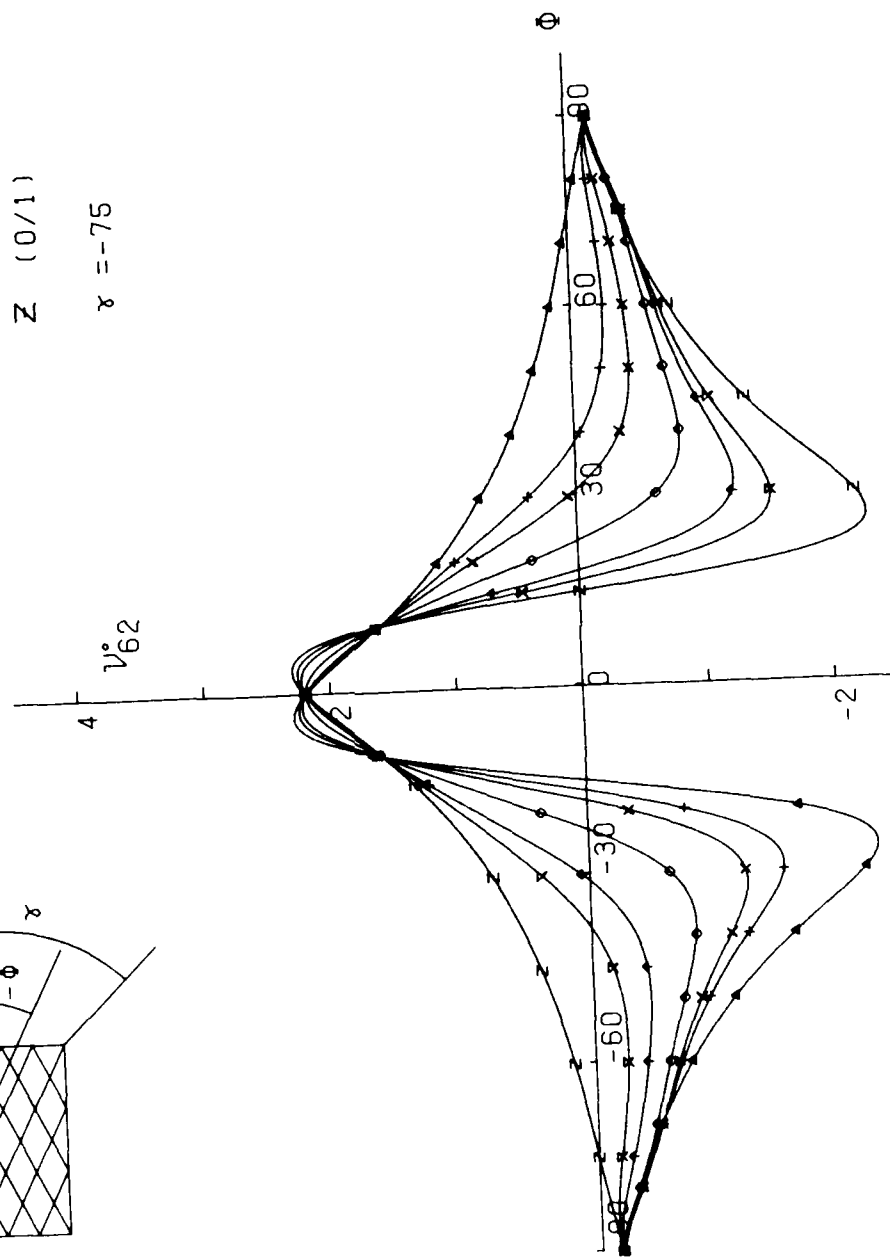
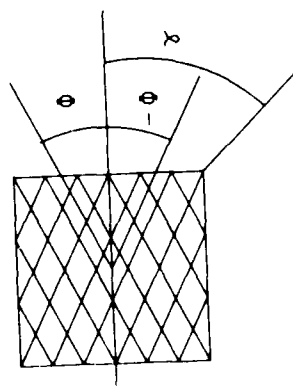


FIG.: 241

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\gamma = -60$

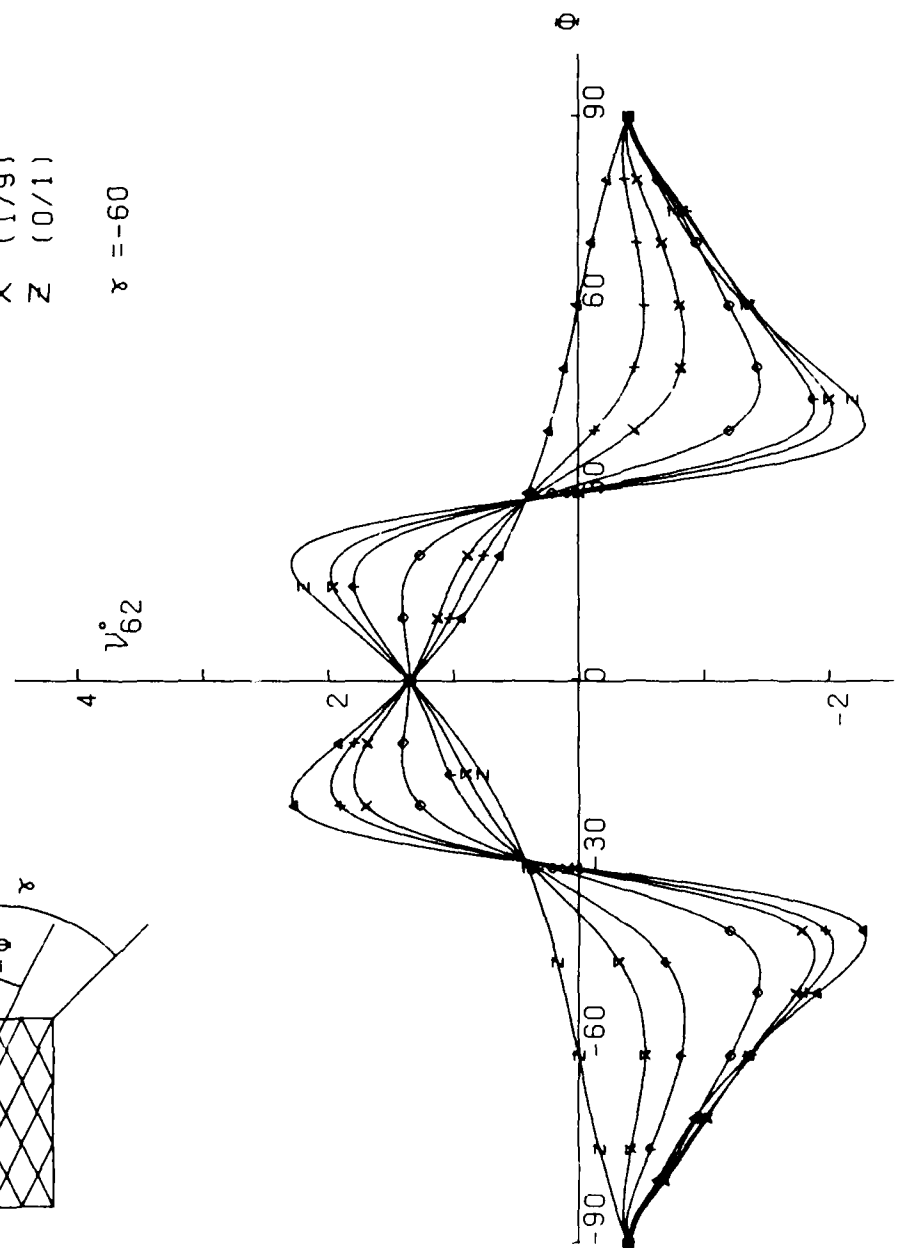
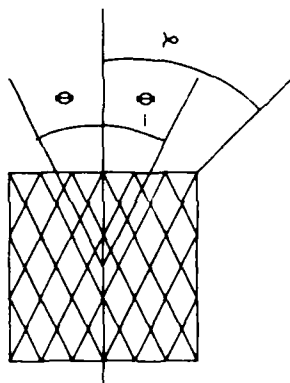
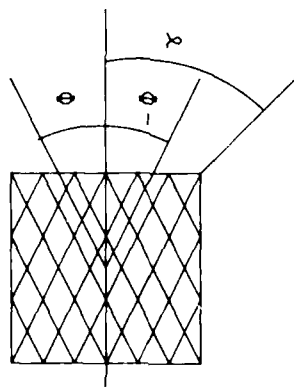


FIG.:242



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\chi = -45$

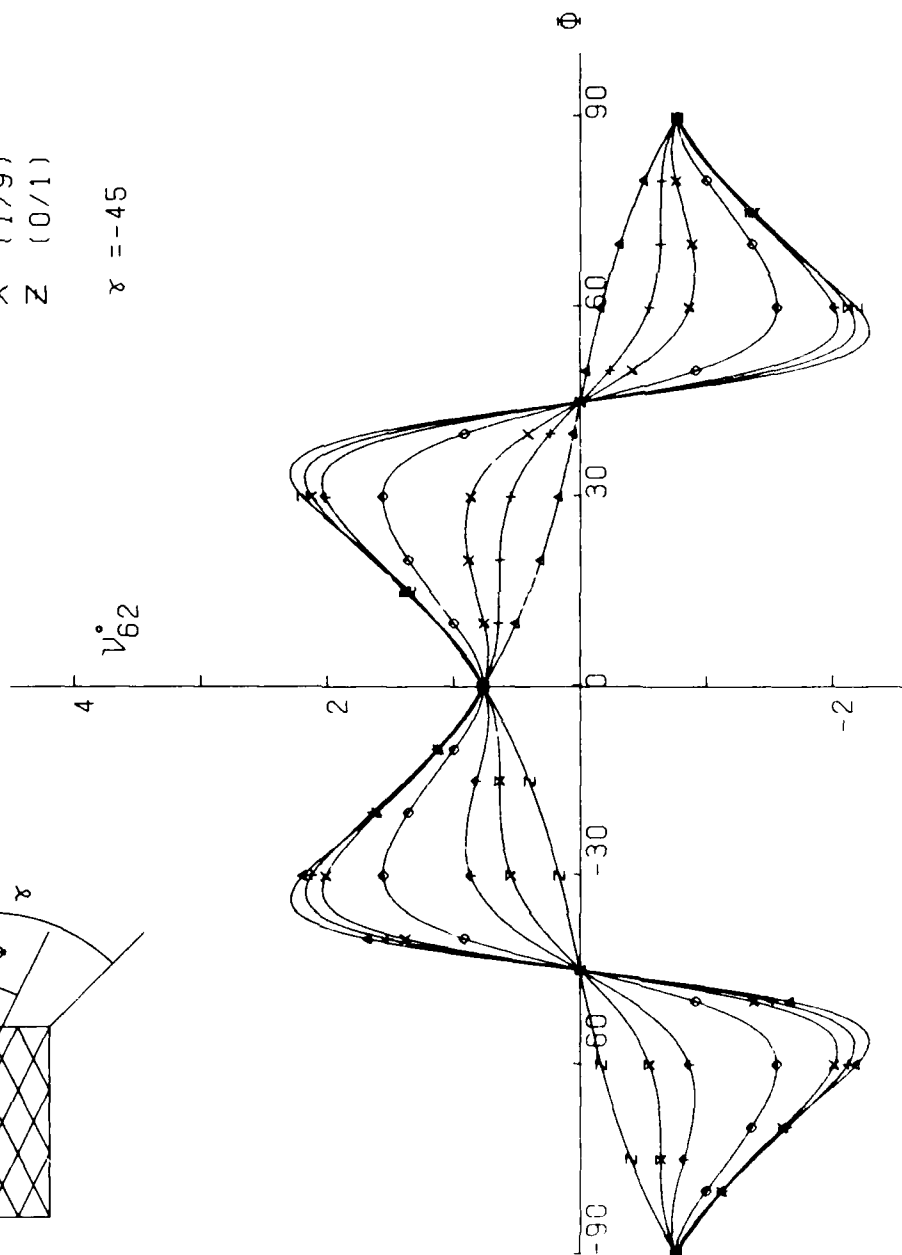


FIG.:243

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\chi = -30$

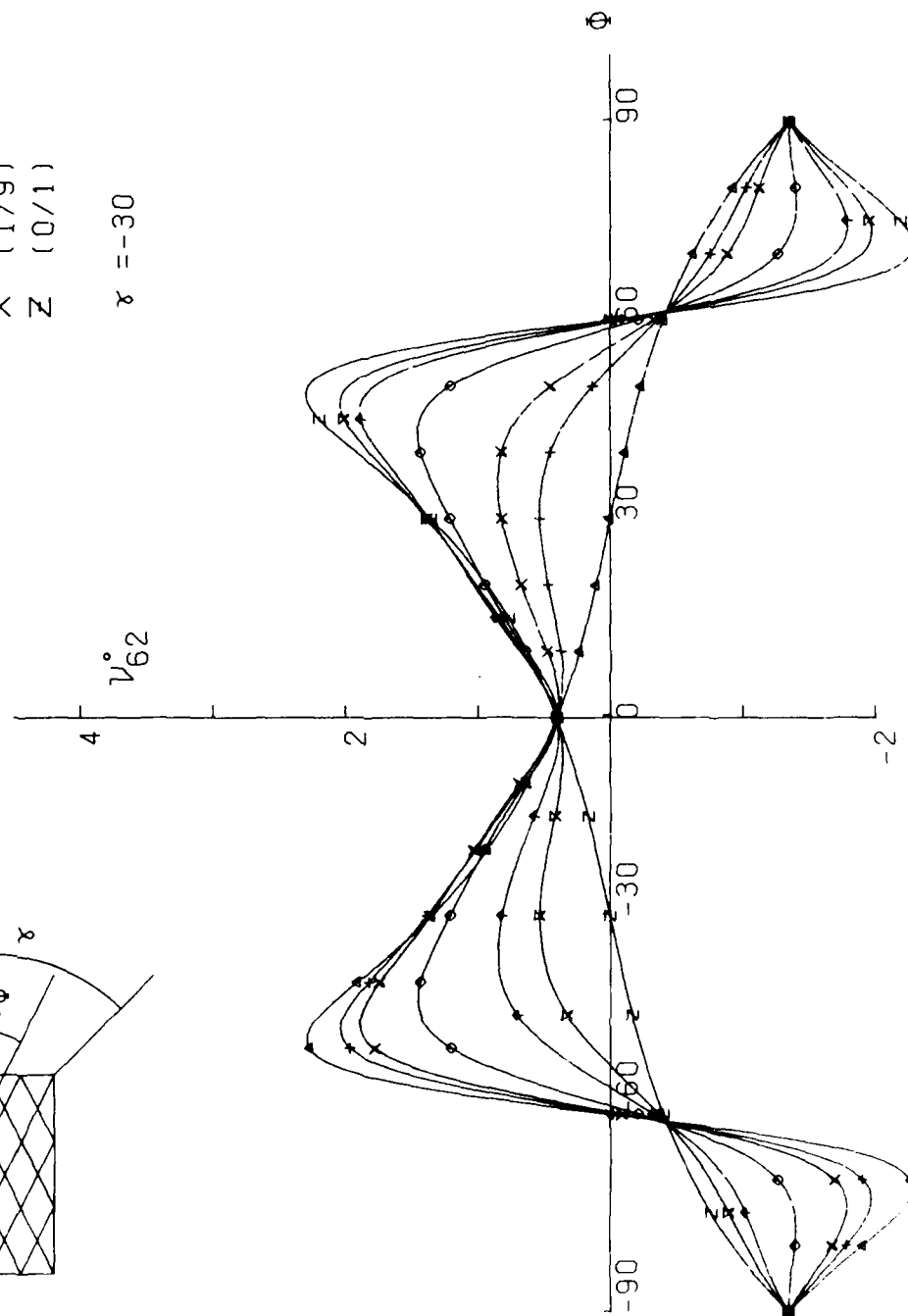
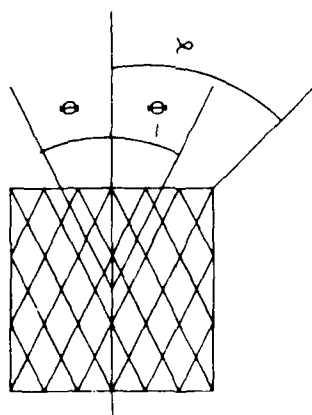


FIG.:244

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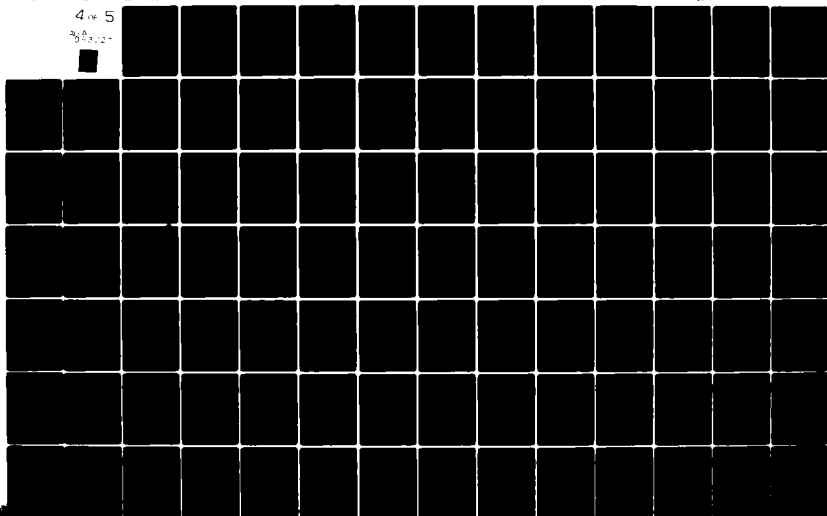
AIR FORCE WRIGHT AERONAUTICAL LABS WRIGHT-PATTERSON AFB OH F/G 11/4
ELASTIC PROPERTIES OF T300/5208 BIDIRECTIONAL SYMMETRIC LAMINAT--ETC(U)
SEP 80 S R SONI
AFWAL-TR-80-4111

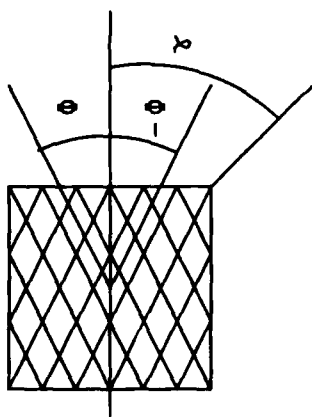
UNCLASSIFIED

NL

4 OF 5

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ϕ/Φ

Δ	+	X	\diamond	∇	\times	Z
(1/0)	(9/1)	(4/1)	(1/1)	(1/4)	(1/9)	(0/1)

$\gamma = -15$

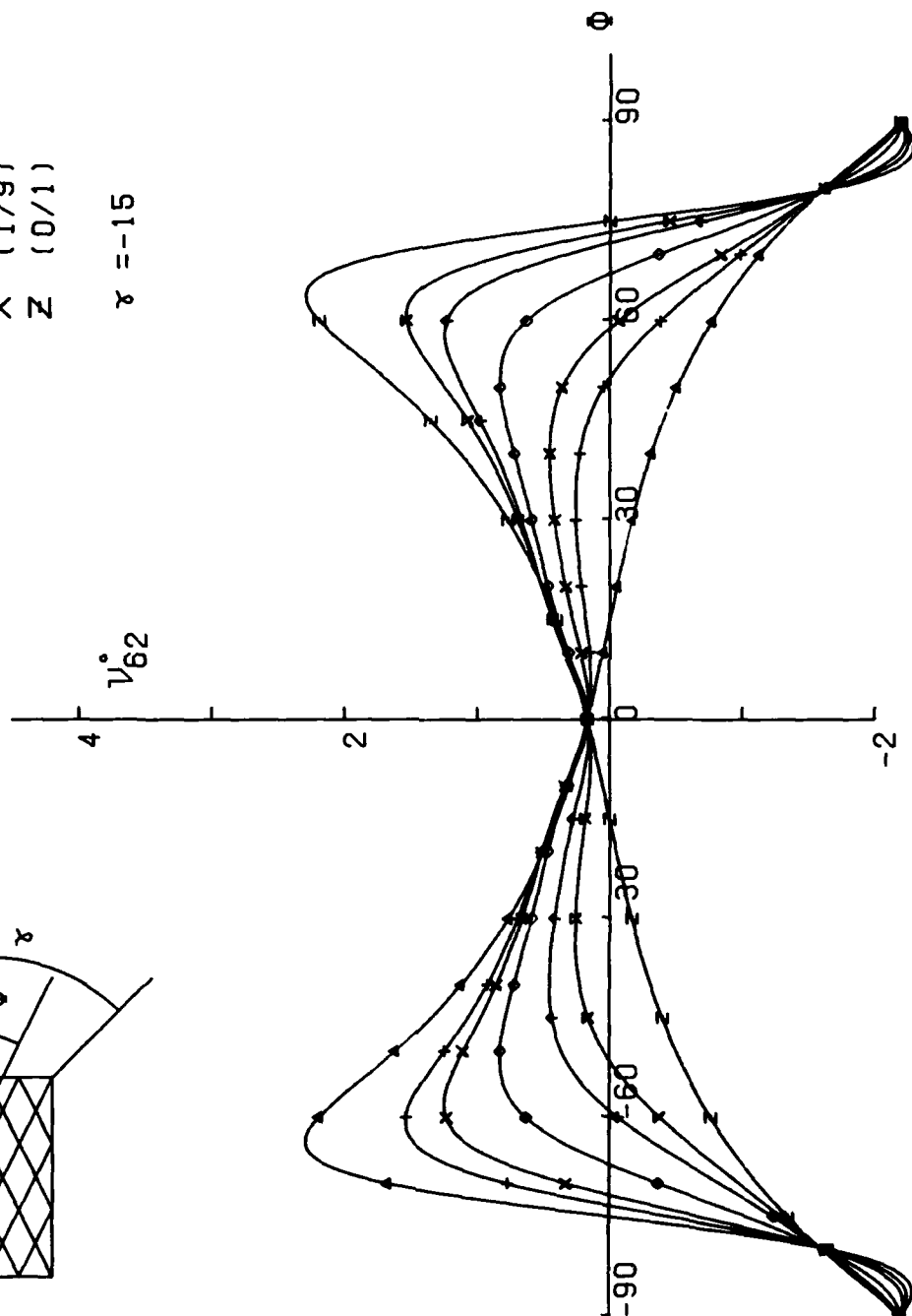


FIG.:245

Φ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\chi = 0$

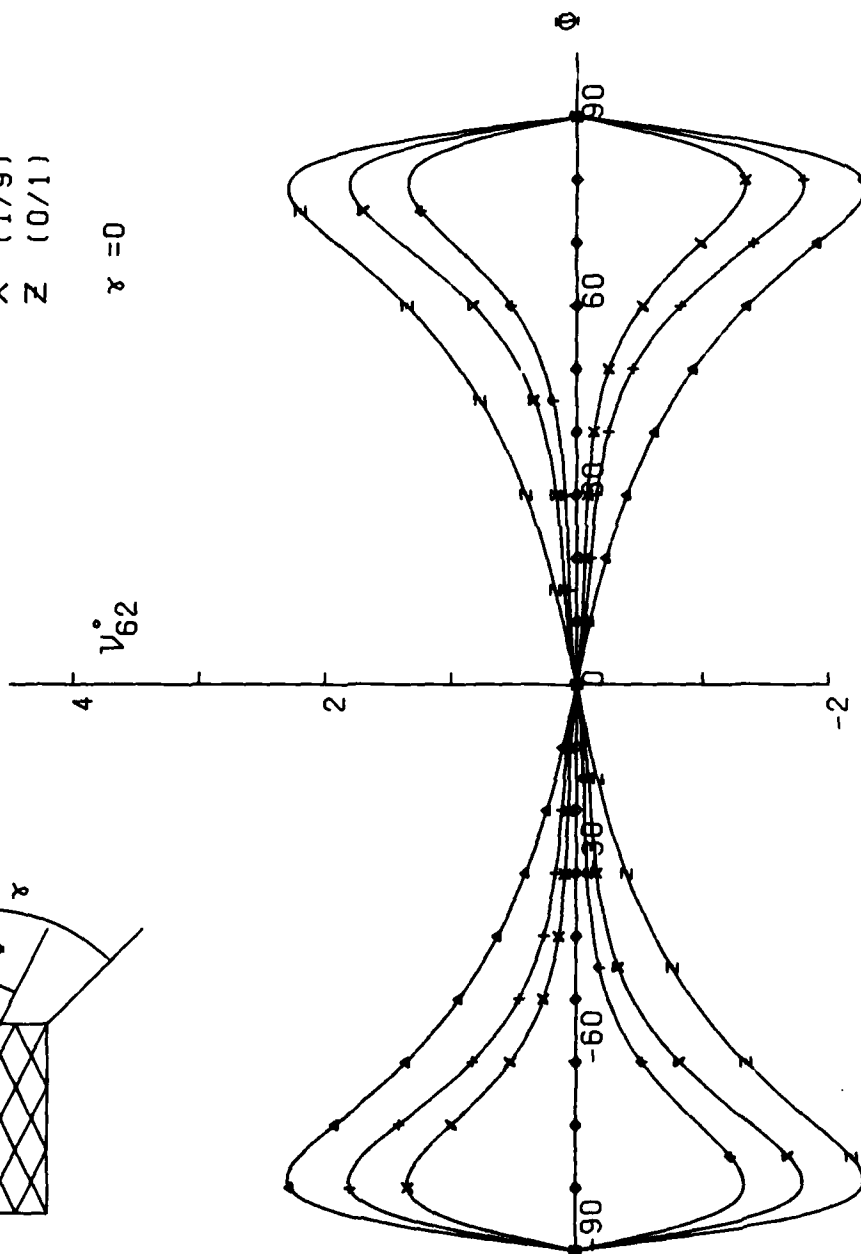
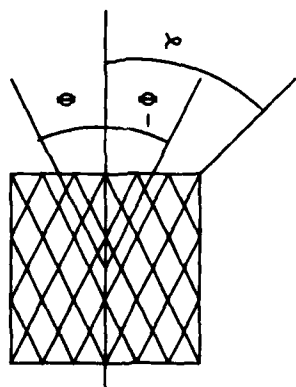


FIG.: 246

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Σ (0/1)

$\gamma = 15$

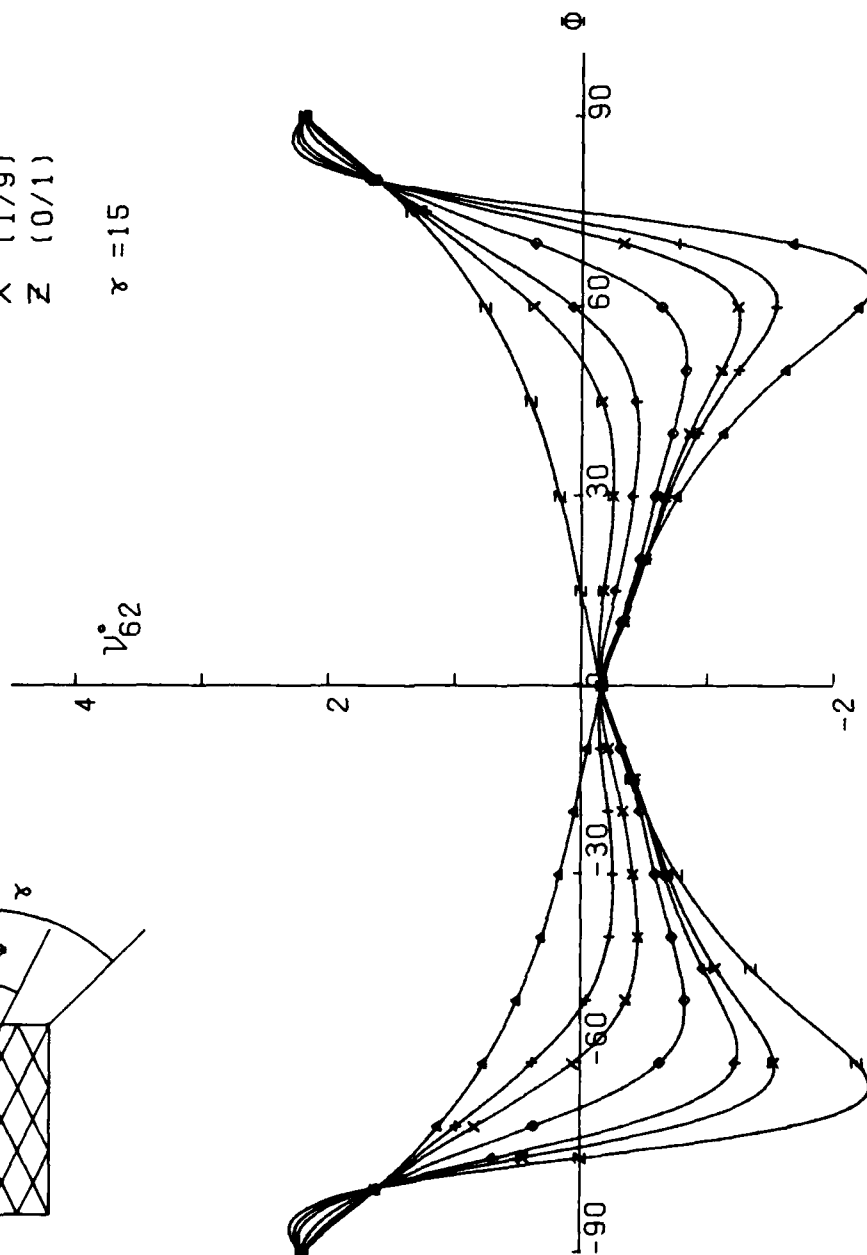
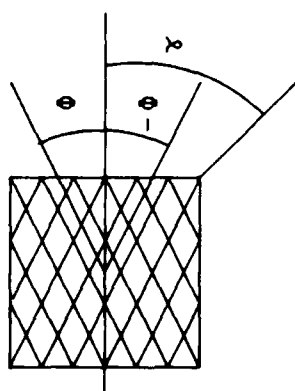


FIG.:247

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 ∇ (0/1)

$\gamma = 30$

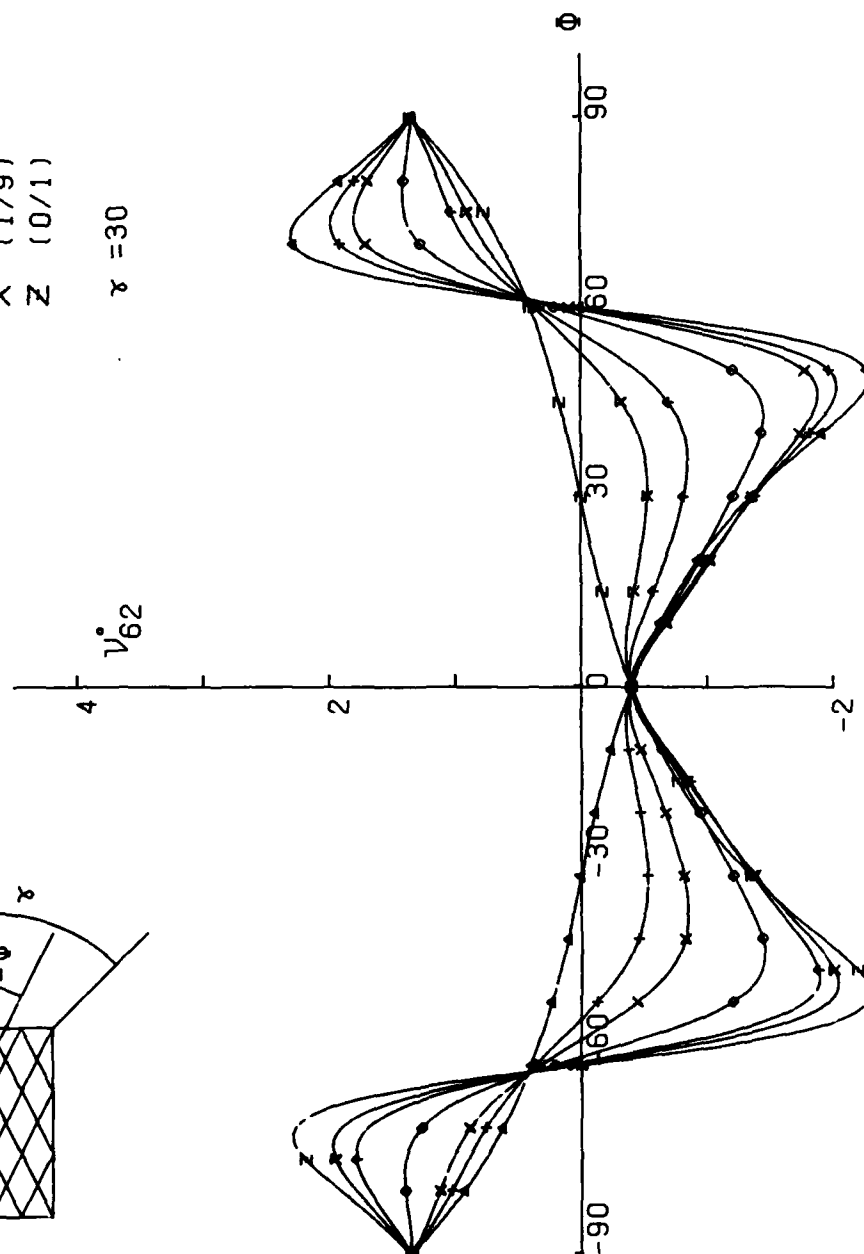
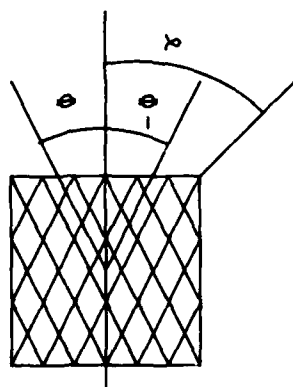


FIG.:248

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Z (0/1)

$\gamma = 45$

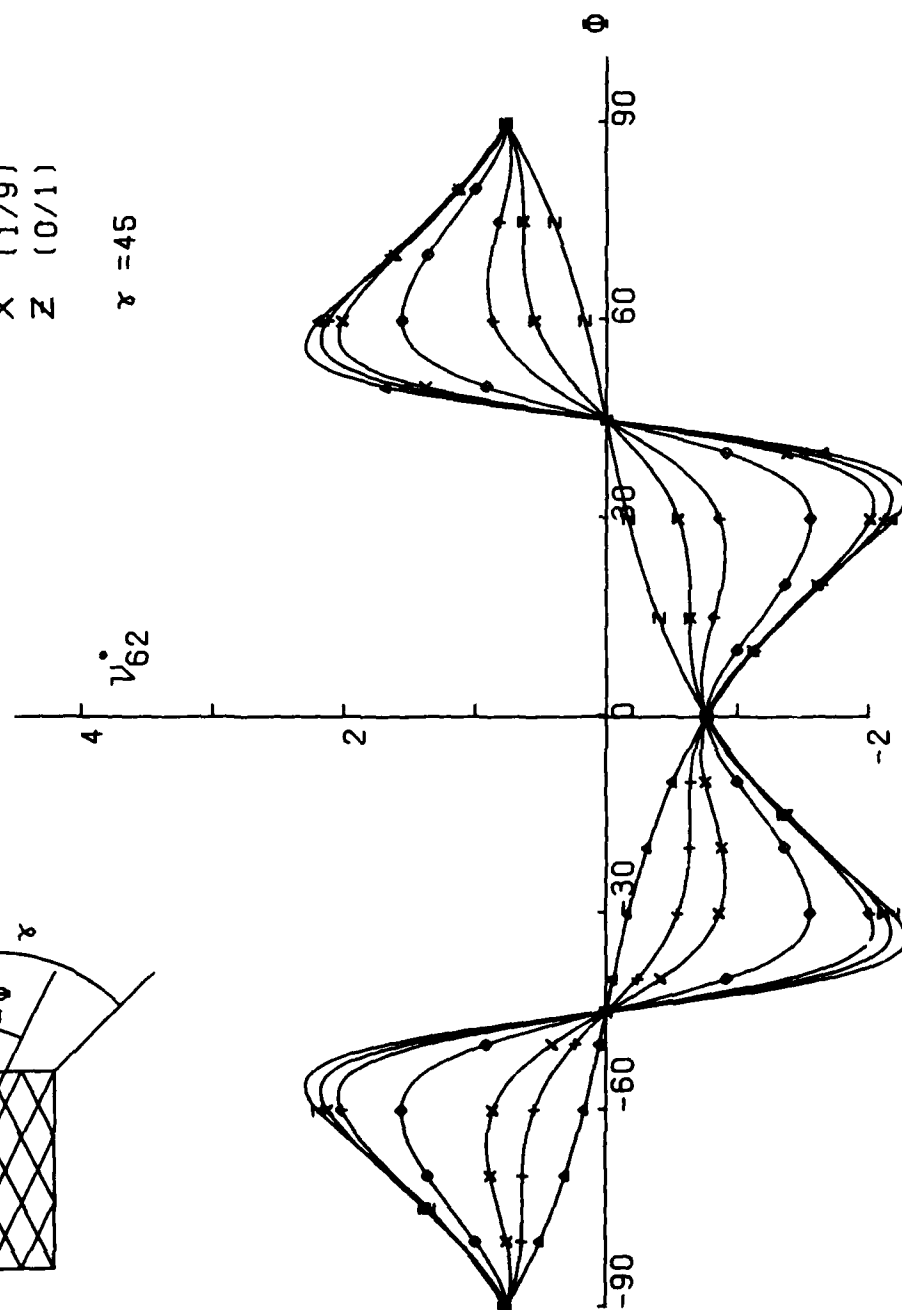
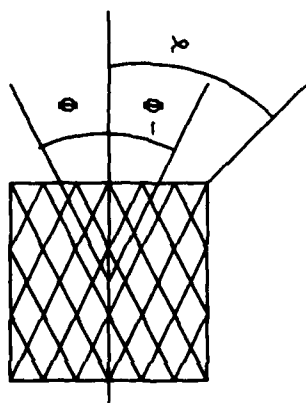


FIG.:249

Φ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = 60$

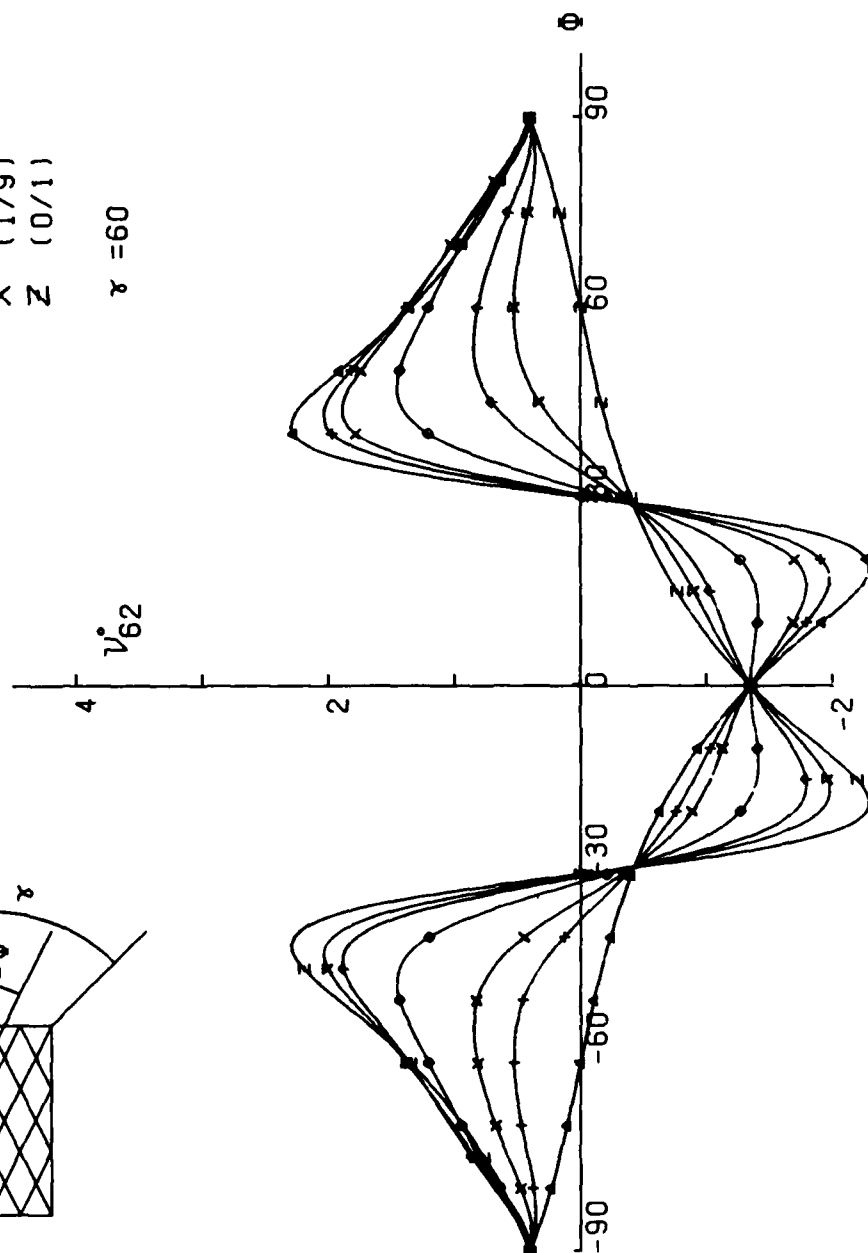
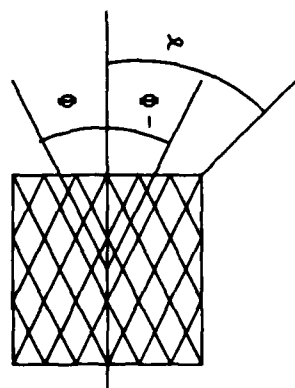


FIG.: 250

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\gamma = 75$

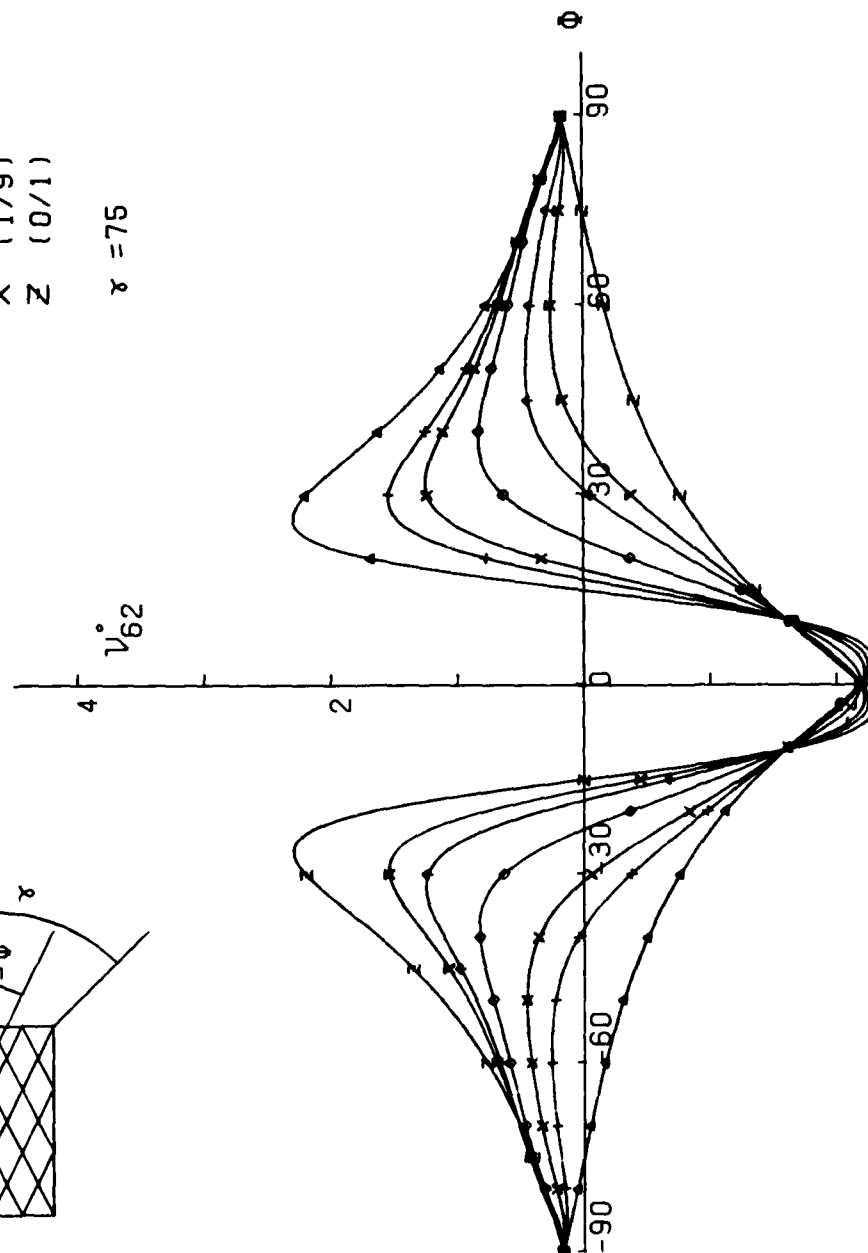
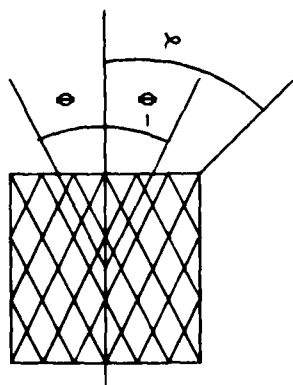


FIG.:251

$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\phi = 15$

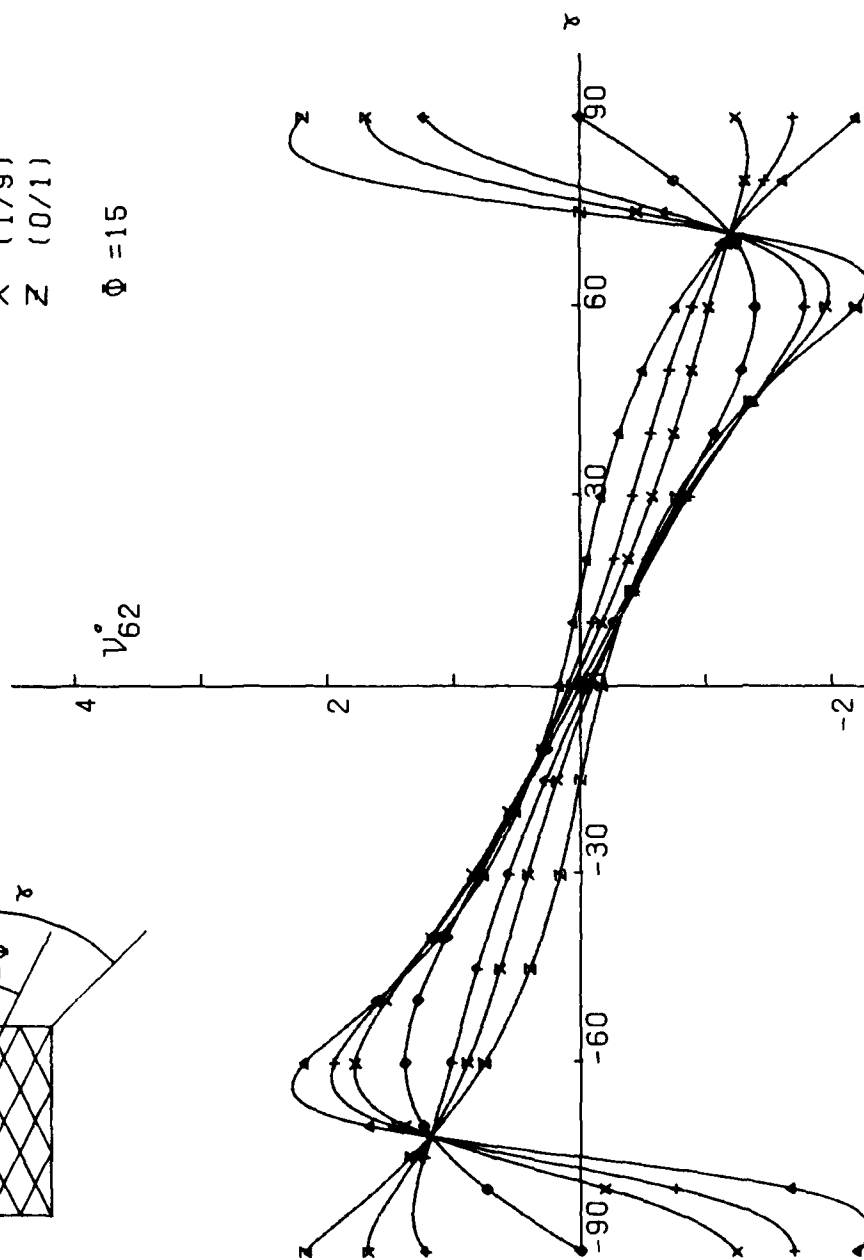
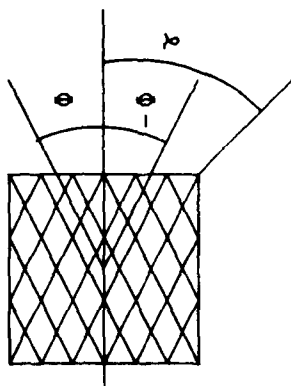


FIG.: 252

$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Σ (0/1)
 $\phi = 30$

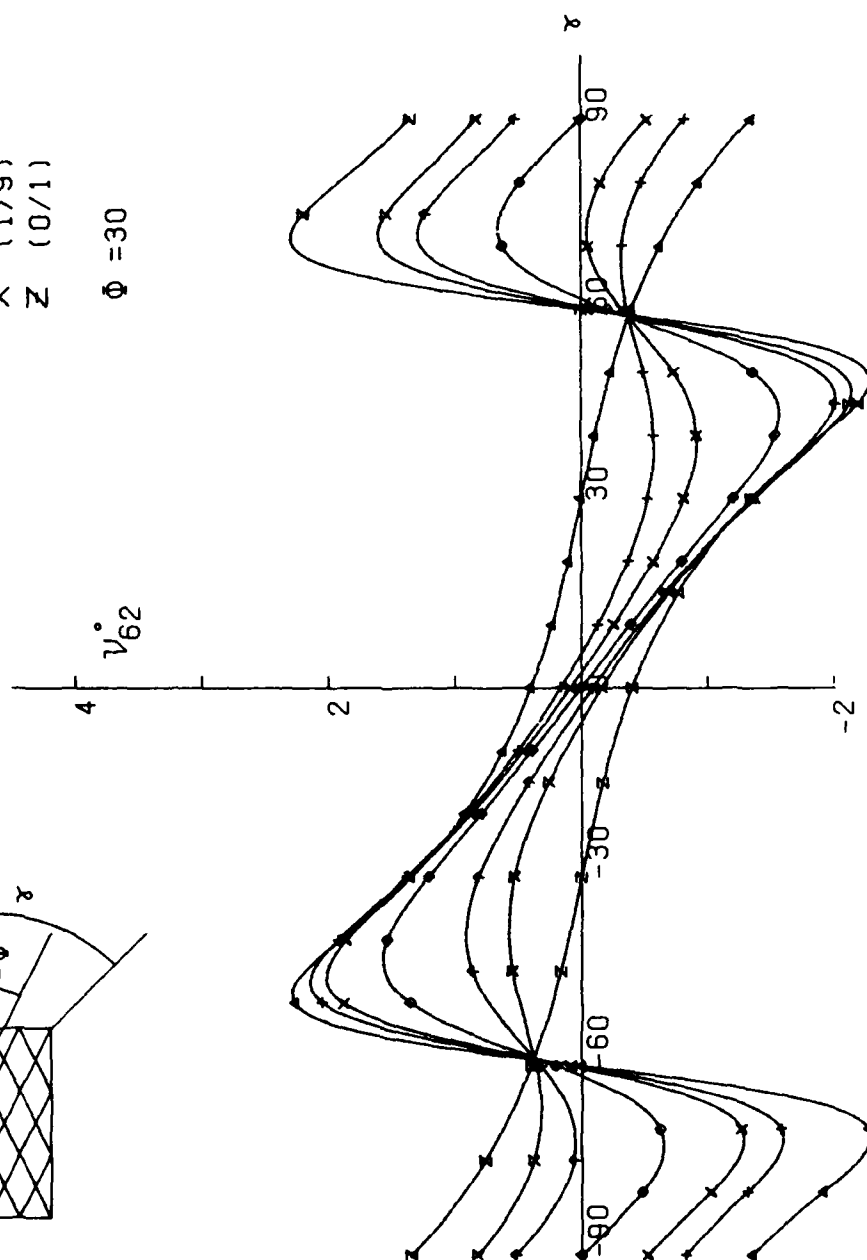
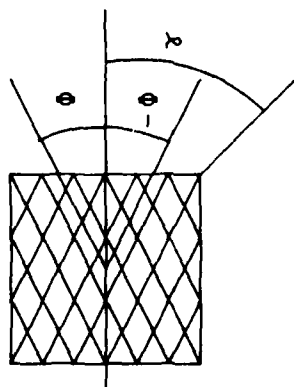


FIG.: 253

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\Phi = 45$

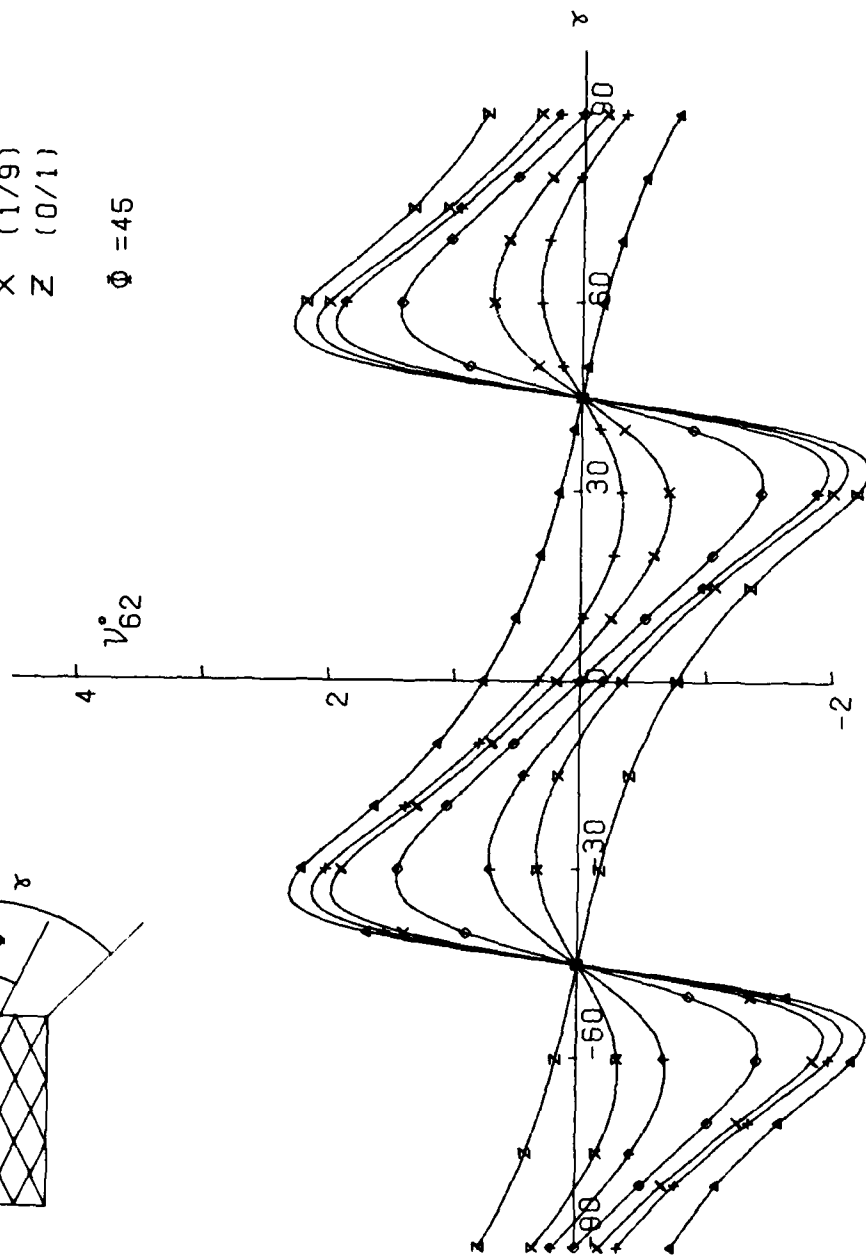
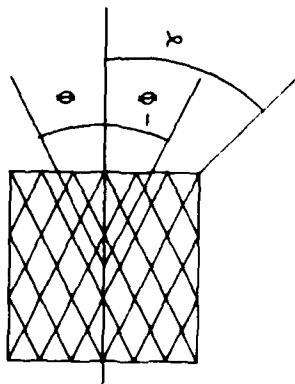


FIG.: 254

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 ∇ (0/1)

$\Phi = 60$

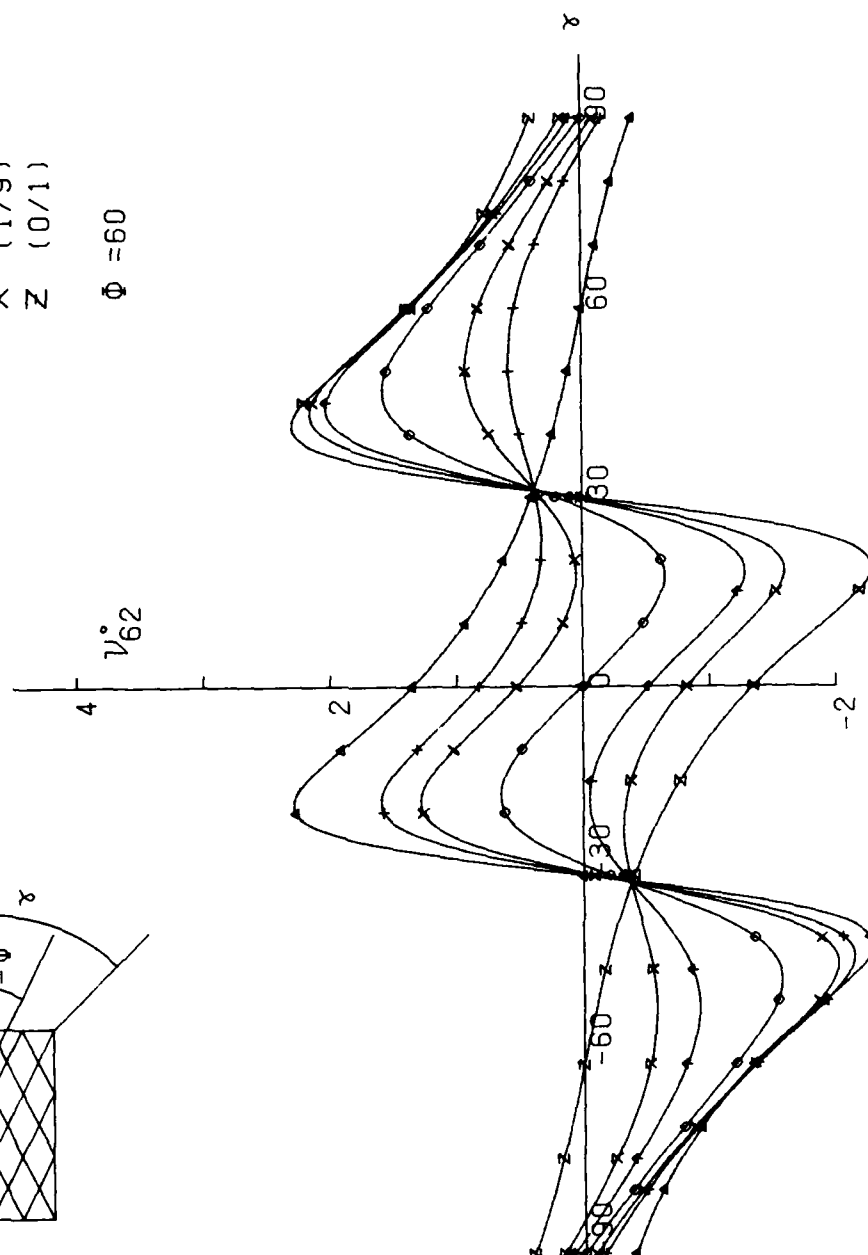
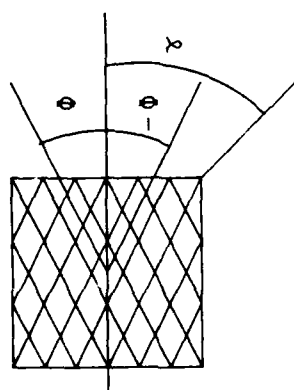


FIG.: 255

$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 ∇ (0/1)
 $\phi = 75$

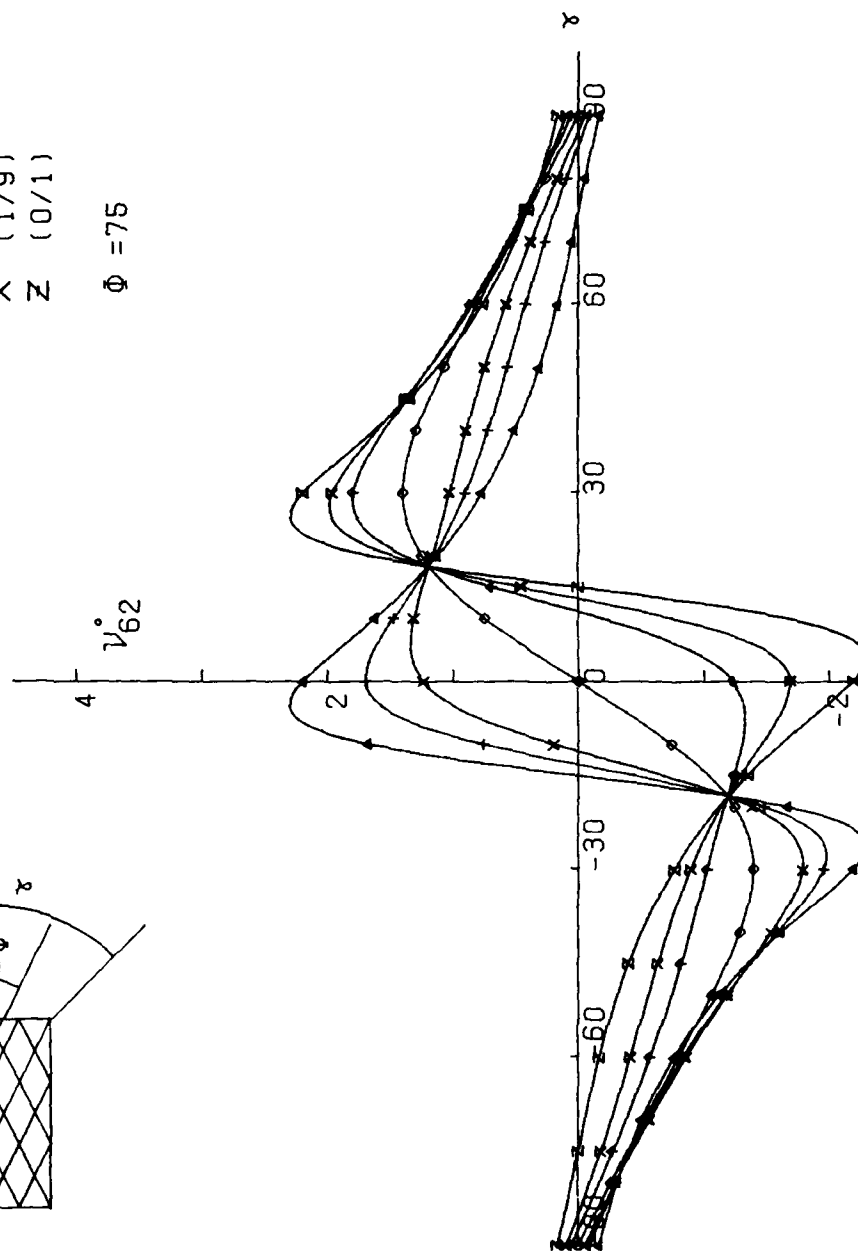
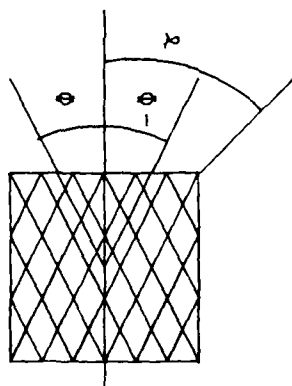


FIG.:256

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = -75$

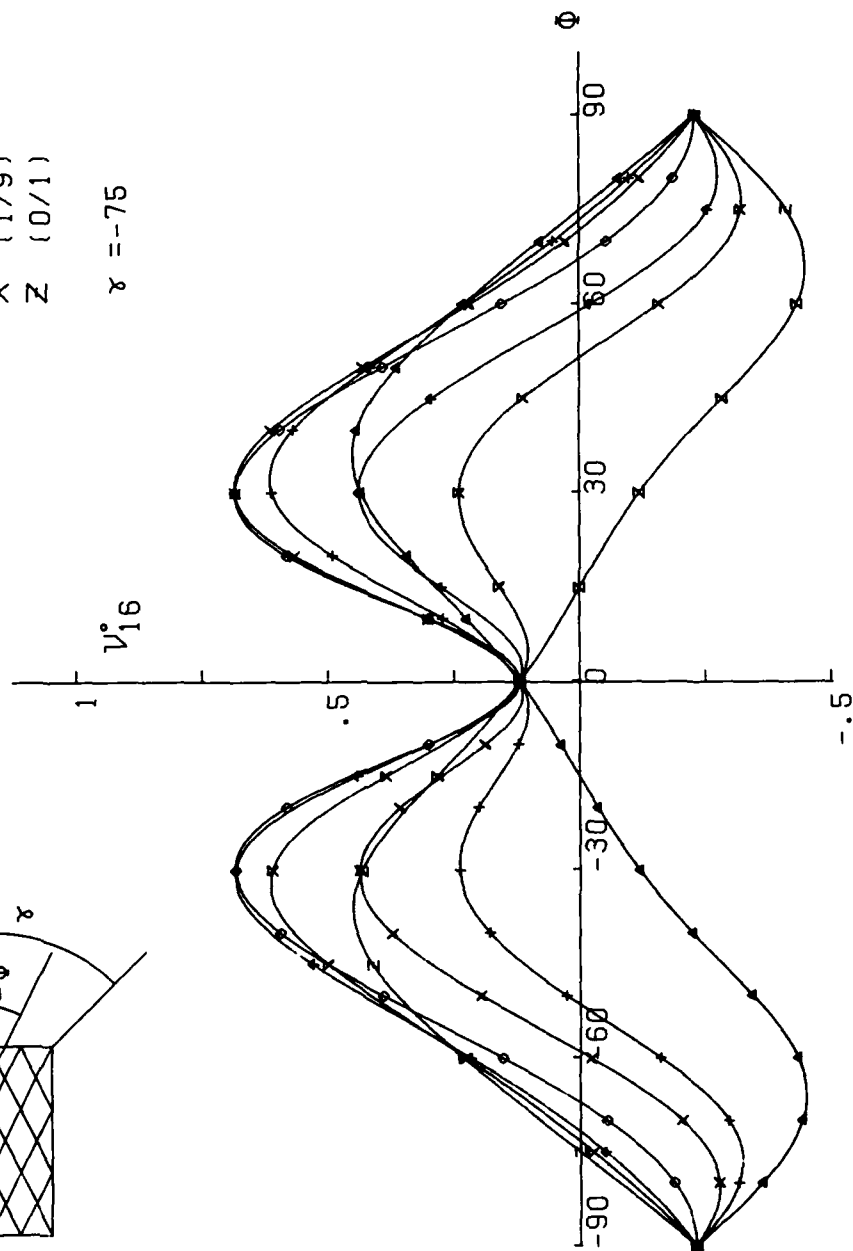
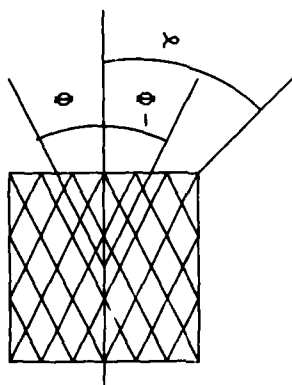


FIG.:257

Φ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\chi = -60$

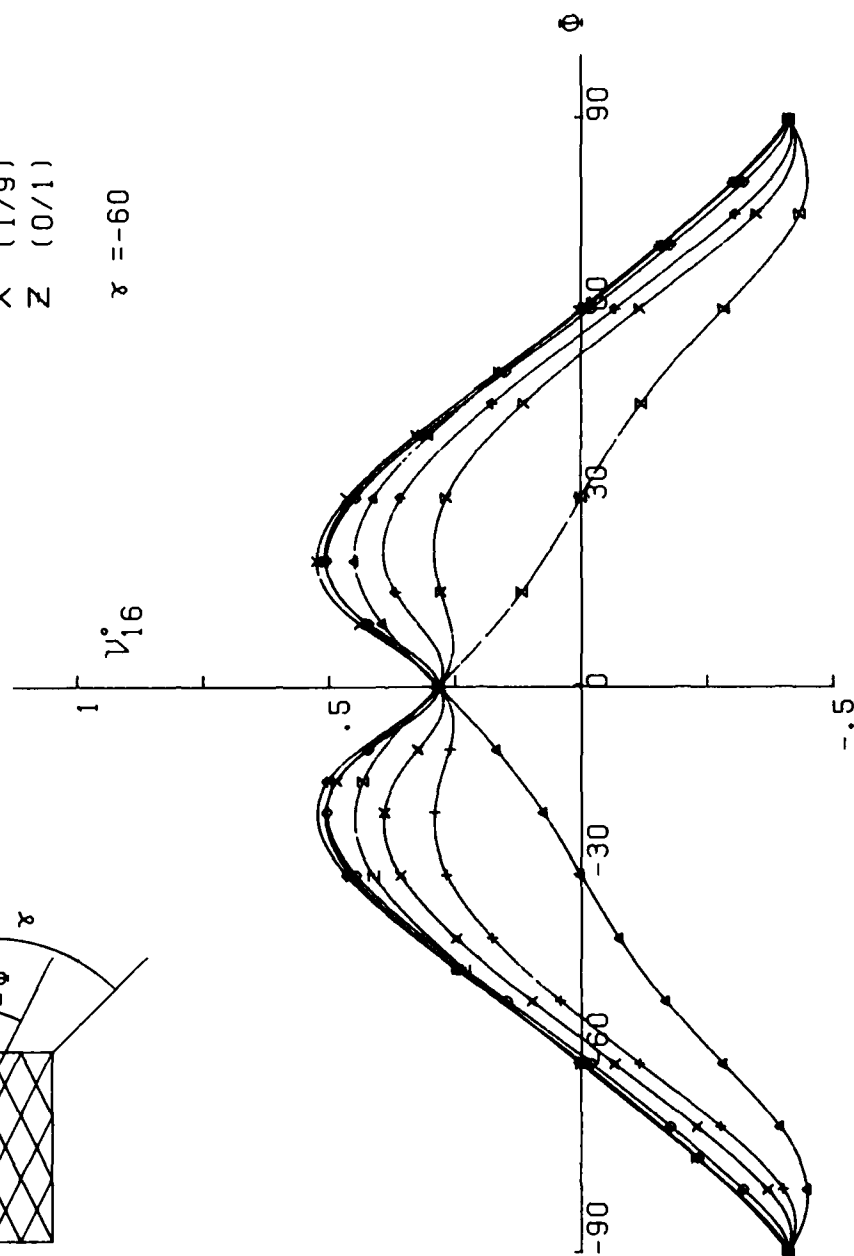
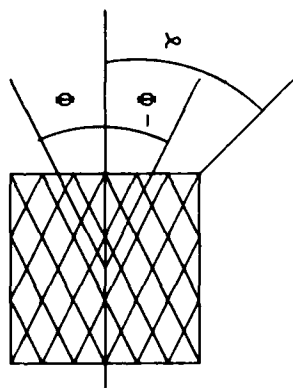


FIG.:258

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = -45$

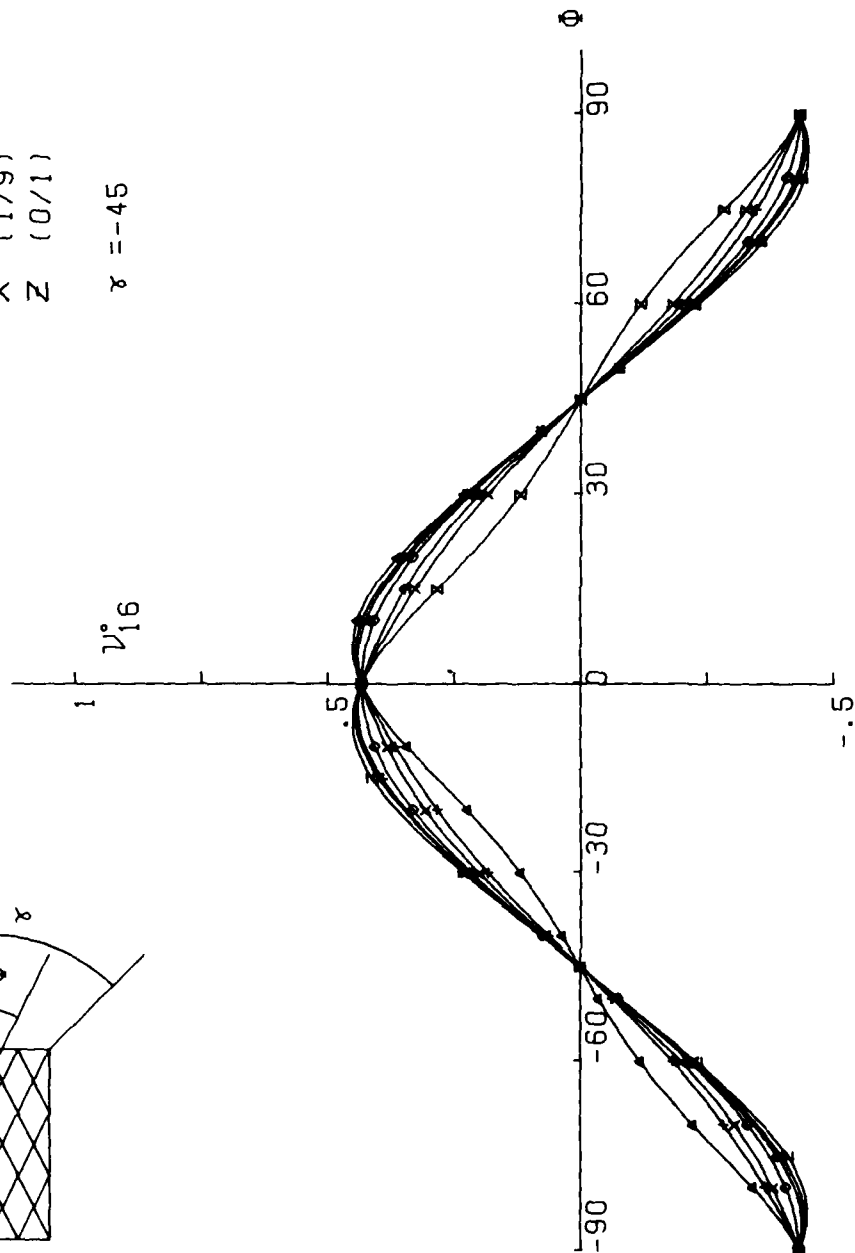
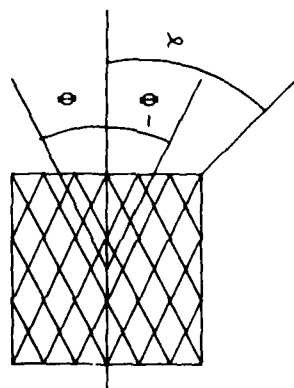


FIG.:259

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\chi = -30$

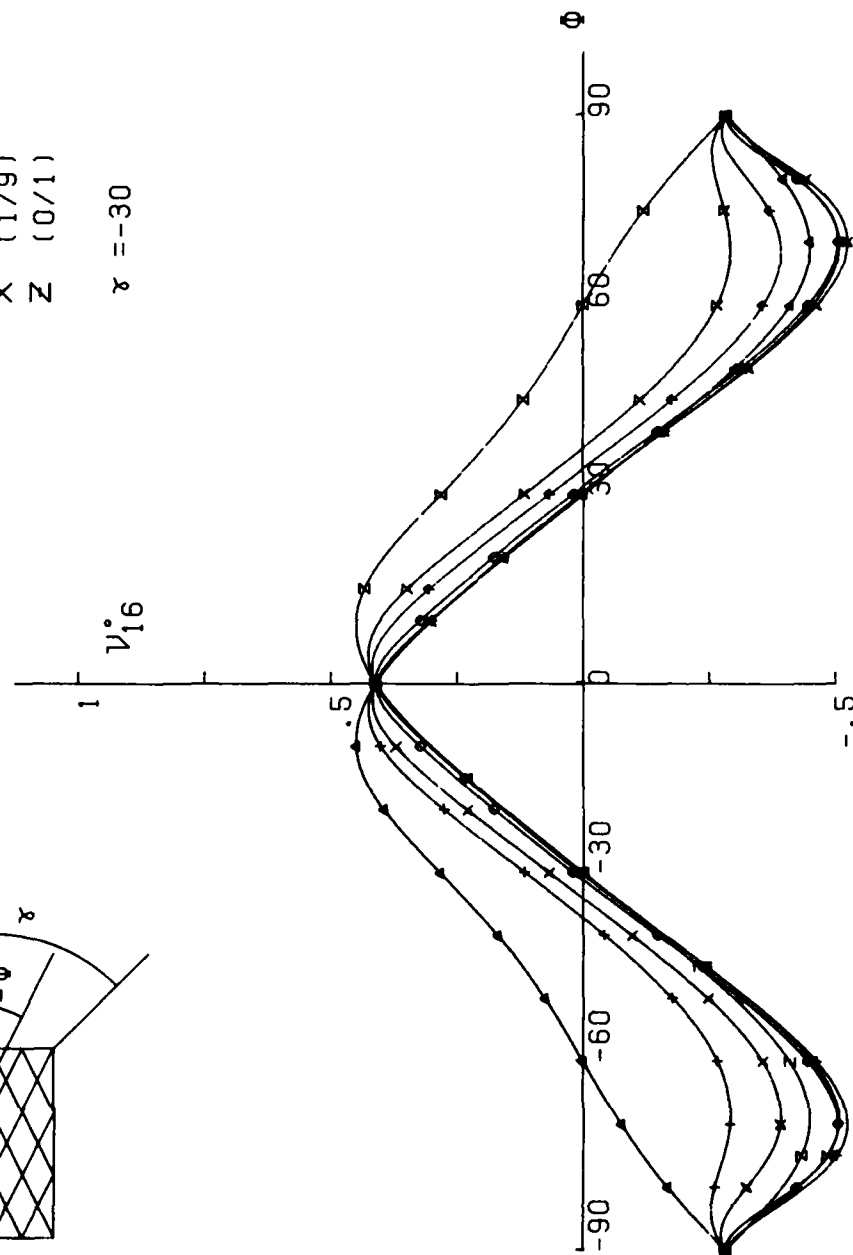
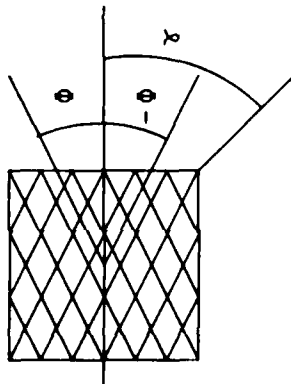
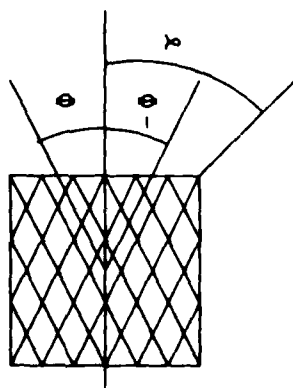


FIG.:260



ϕ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 \times (1/9)
 Z (0/1)

$\gamma = -15$

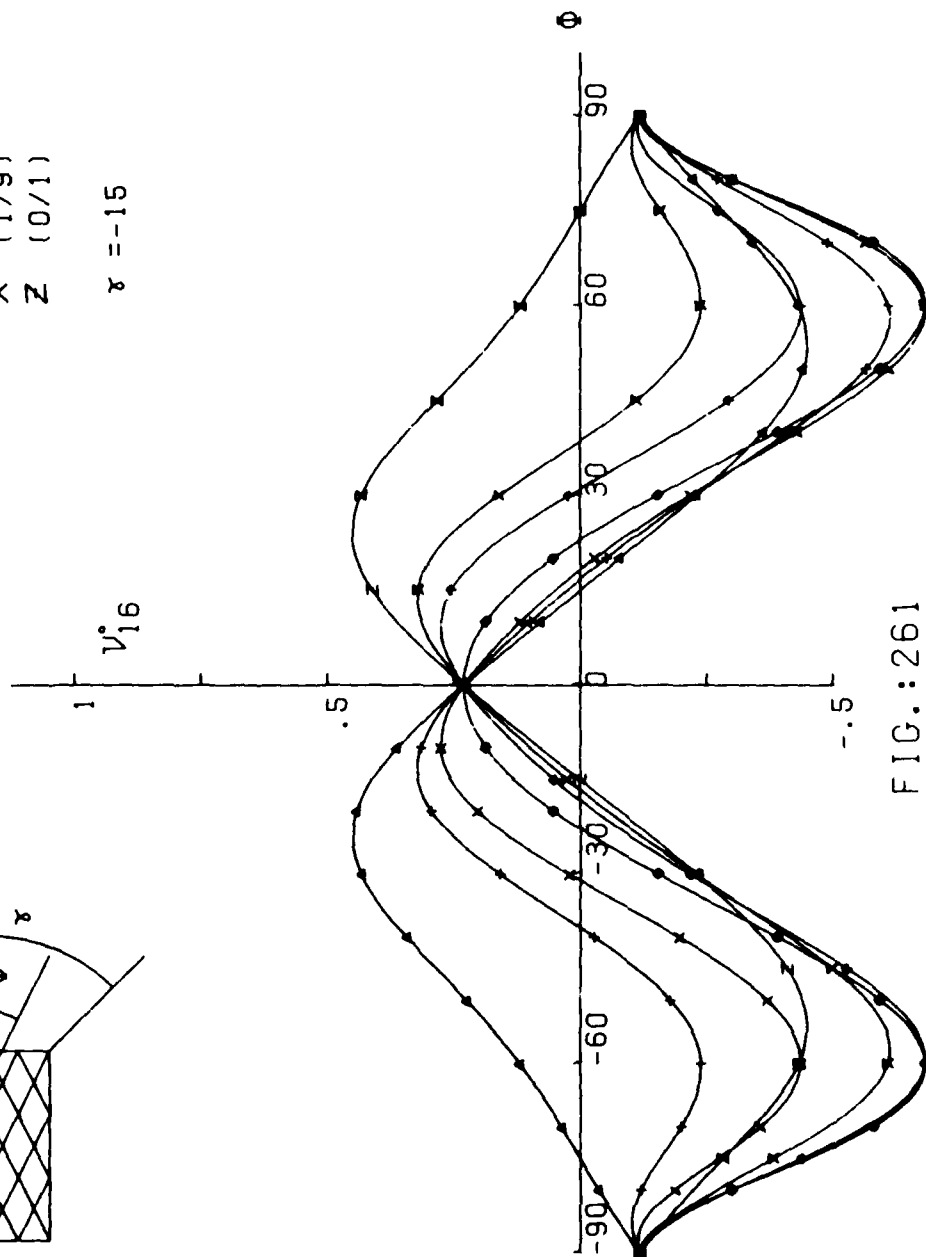


FIG.:261

ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Z (0/1)

$\chi = 0$

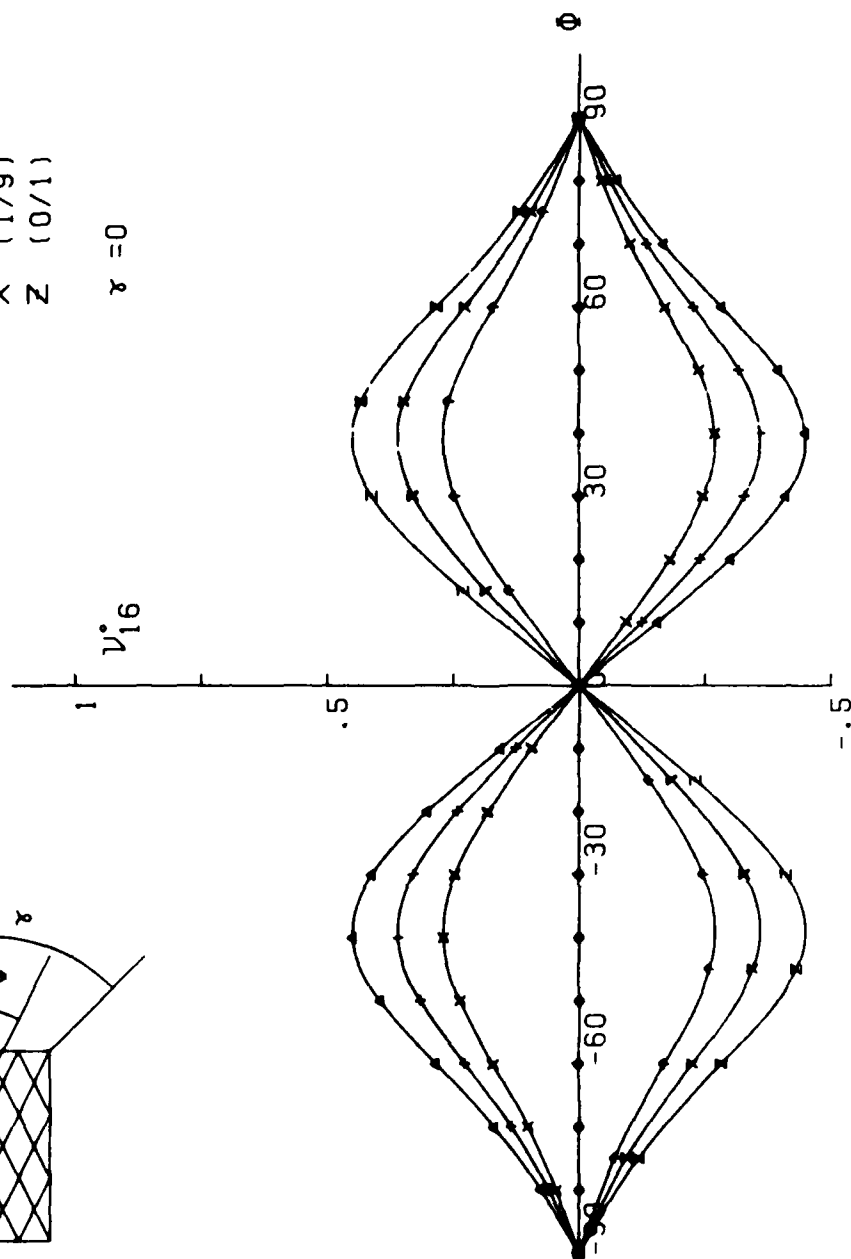
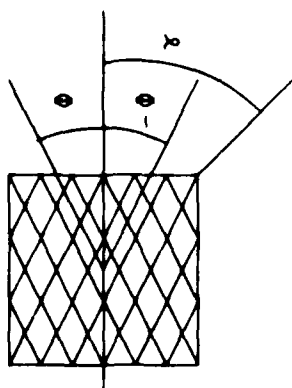
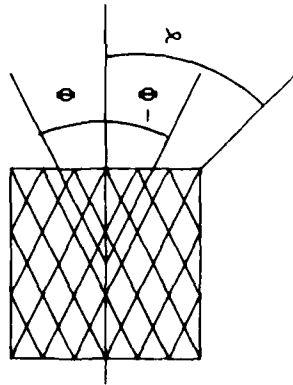


FIG.: 262



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\gamma = 15$

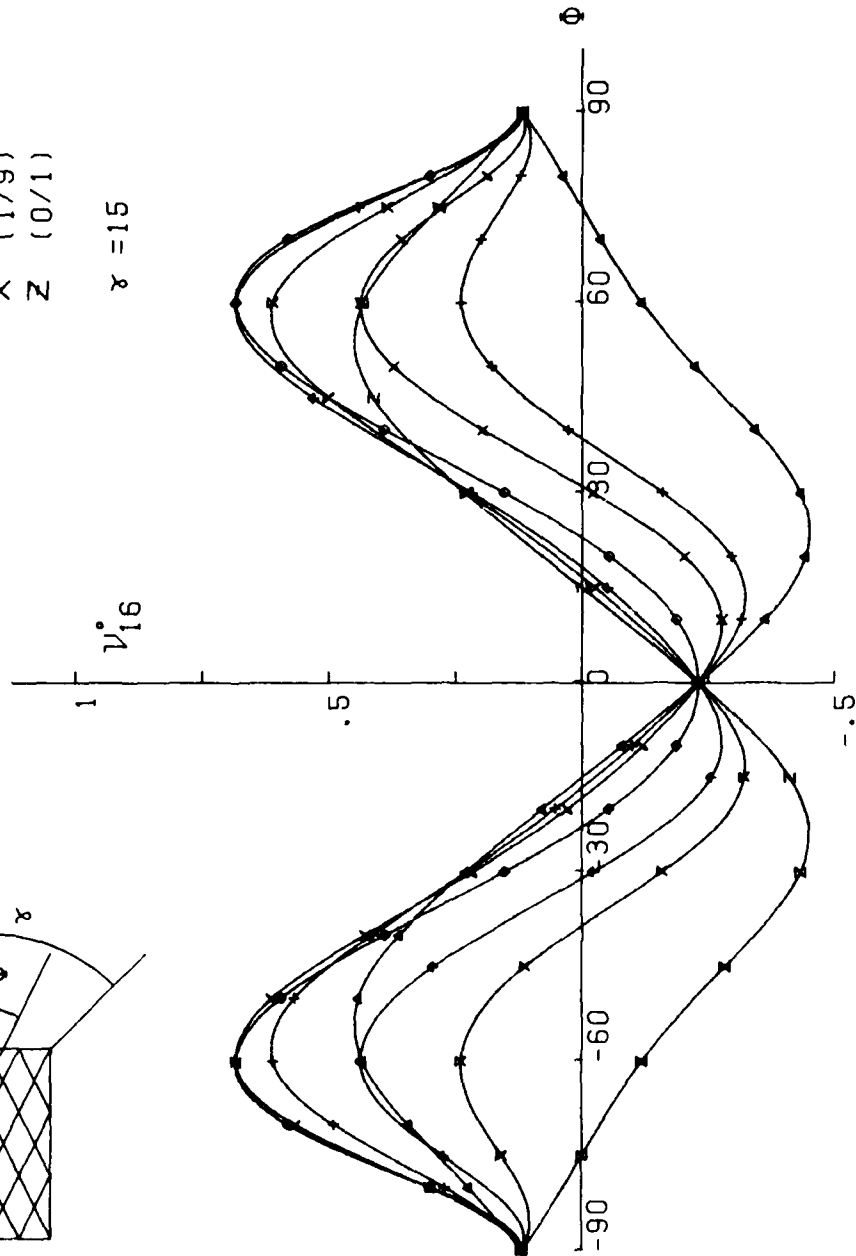


FIG.:263

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Z (0/1)

$\gamma = 30$

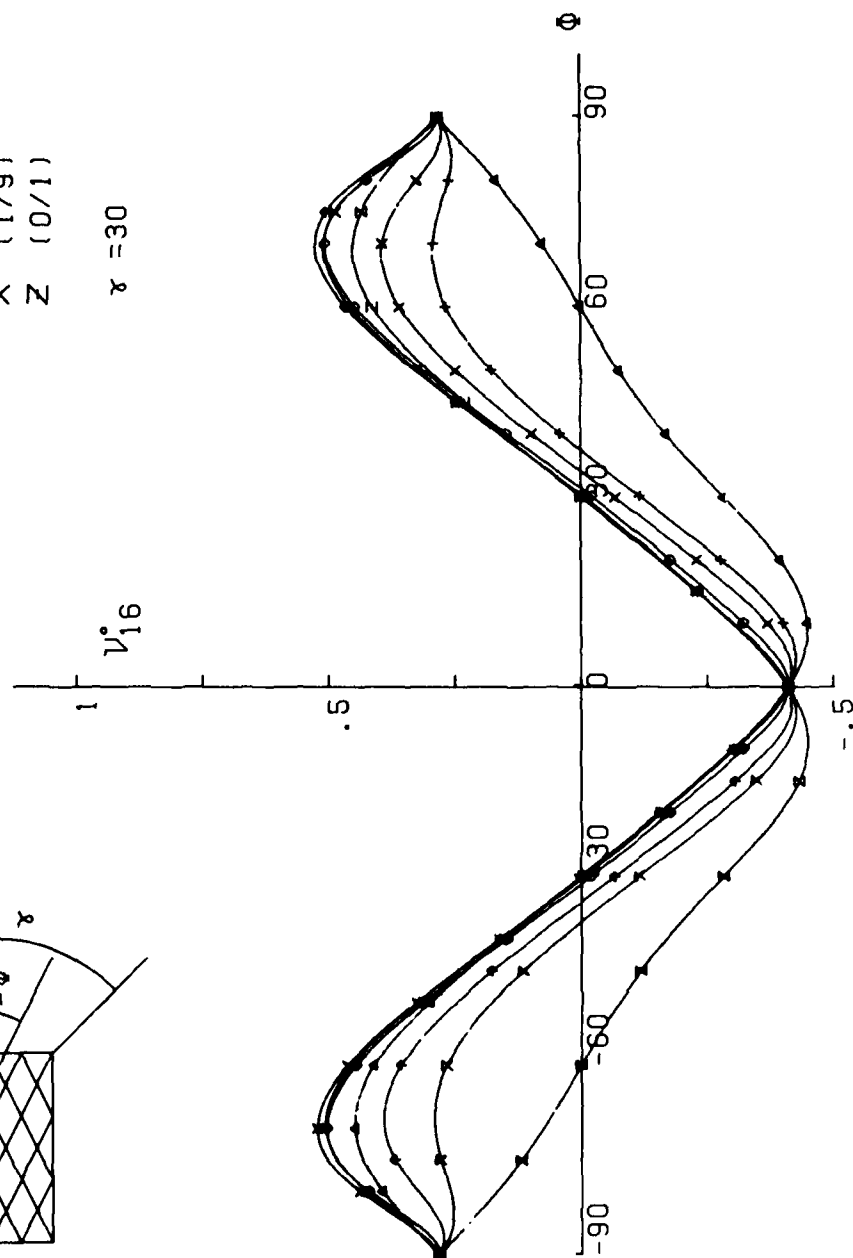
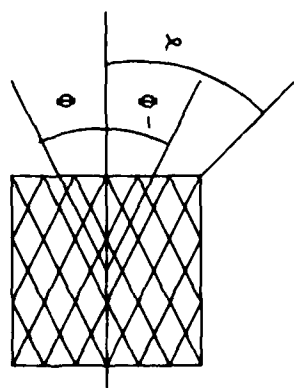


FIG.:264

Φ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\gamma = 45$

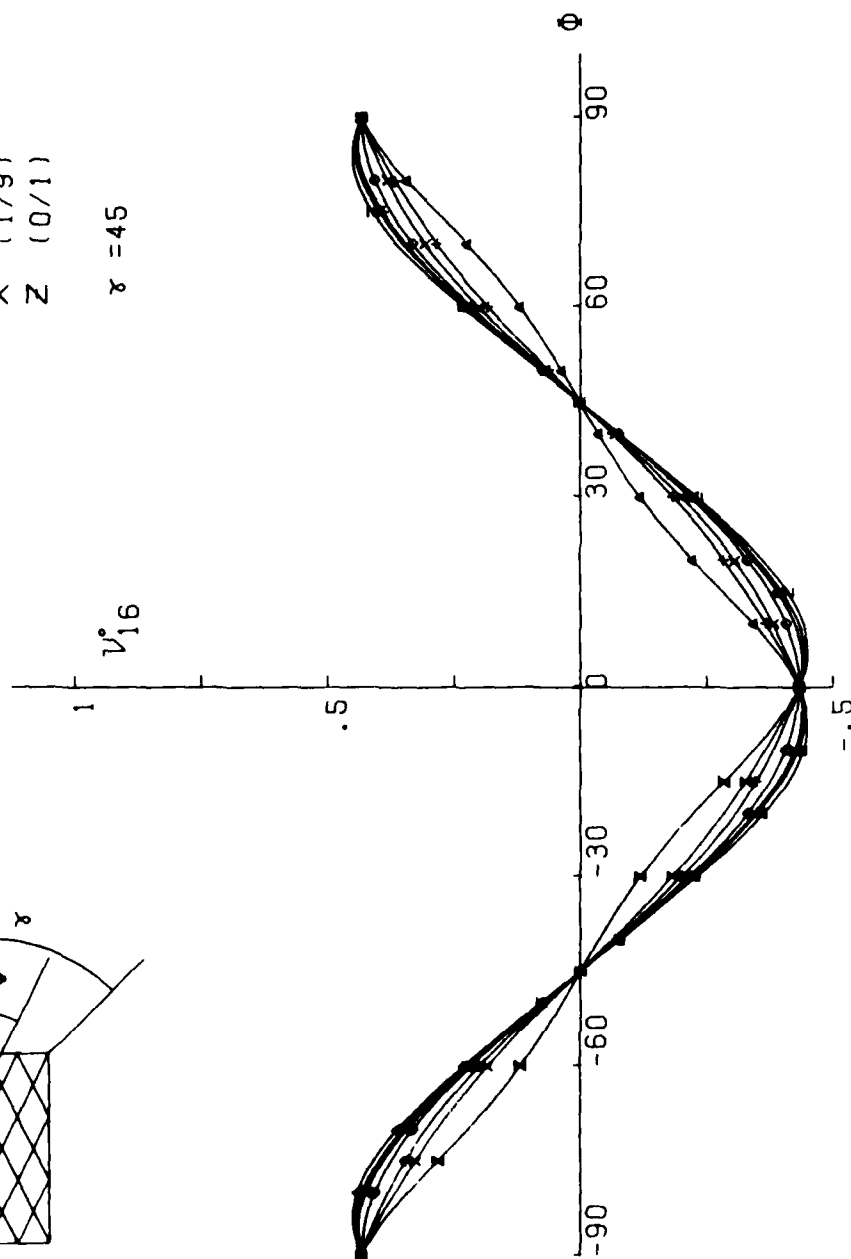
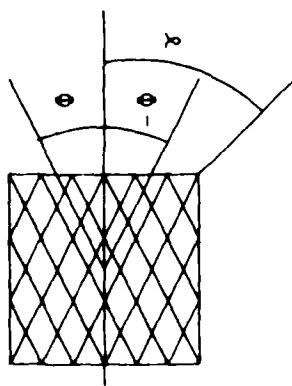
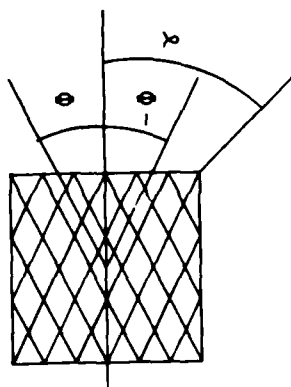


FIG.: 265



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Z (0/1)
 $\chi = 60$

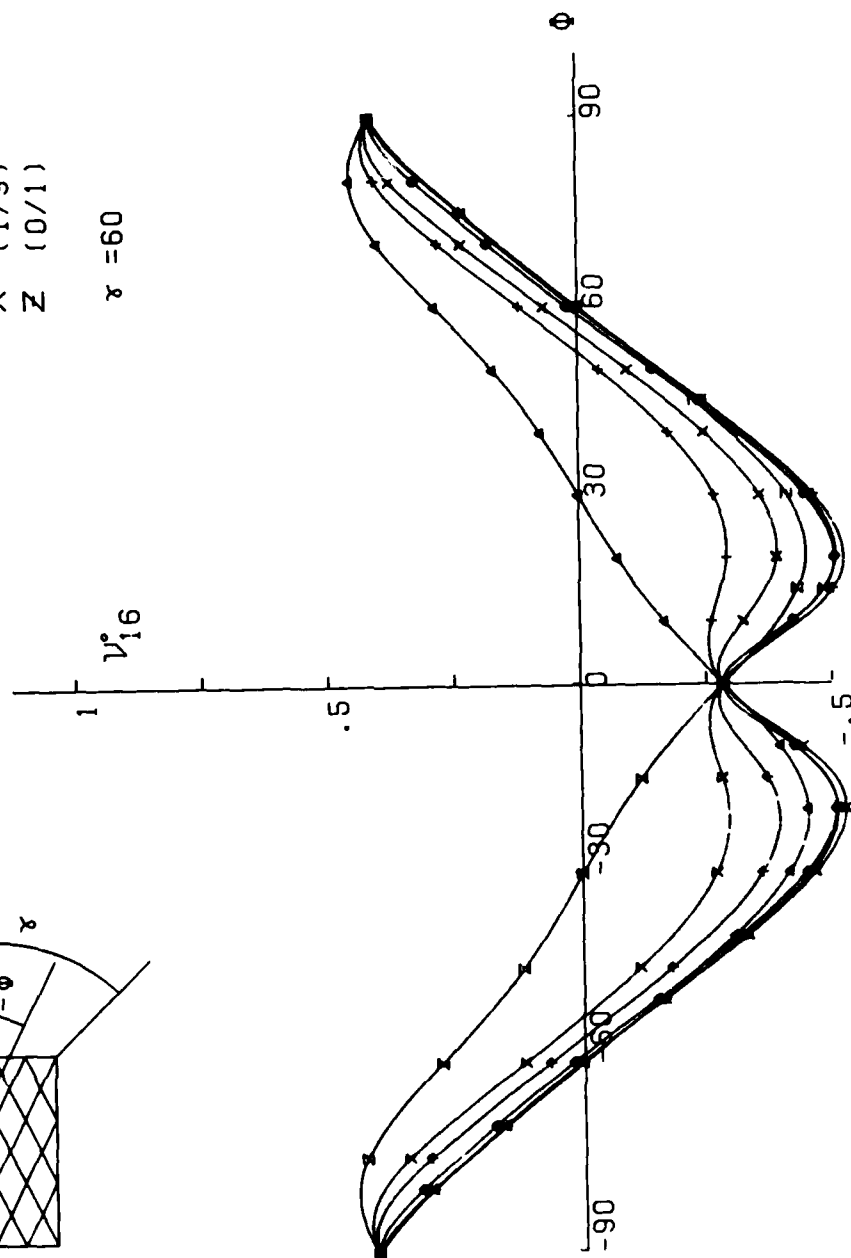


FIG.:266

Φ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\alpha = 75$

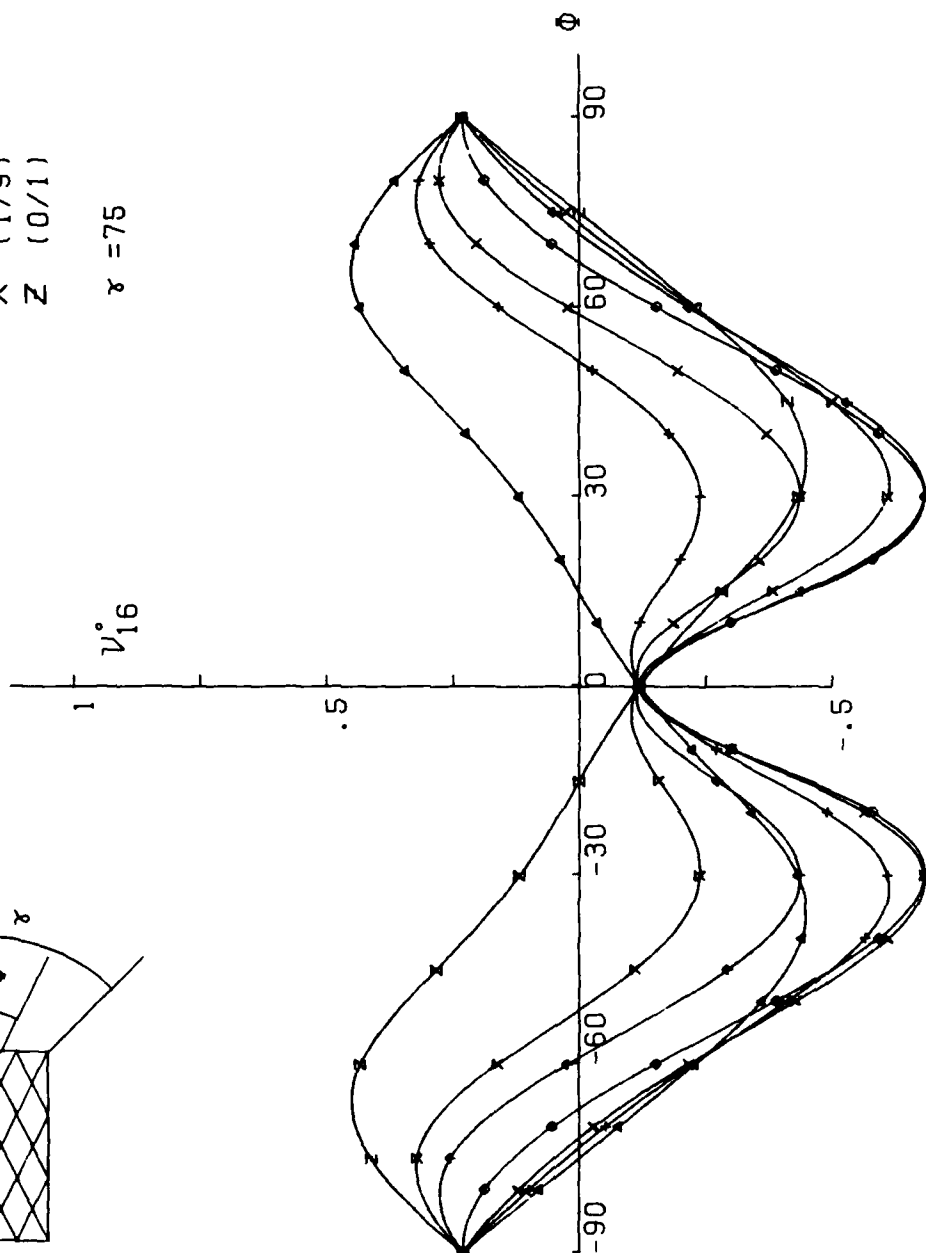
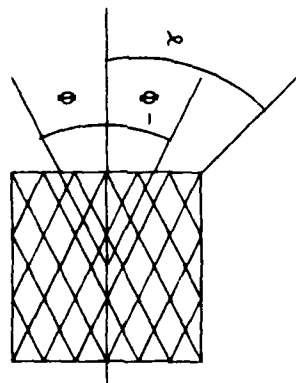
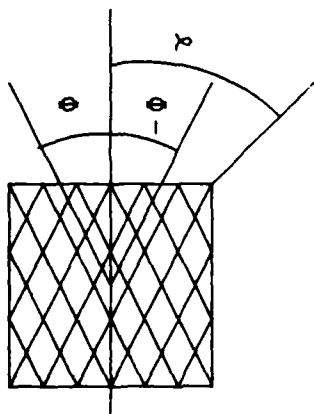


FIG.: 267



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Σ (0/1)
 $\phi = 15$

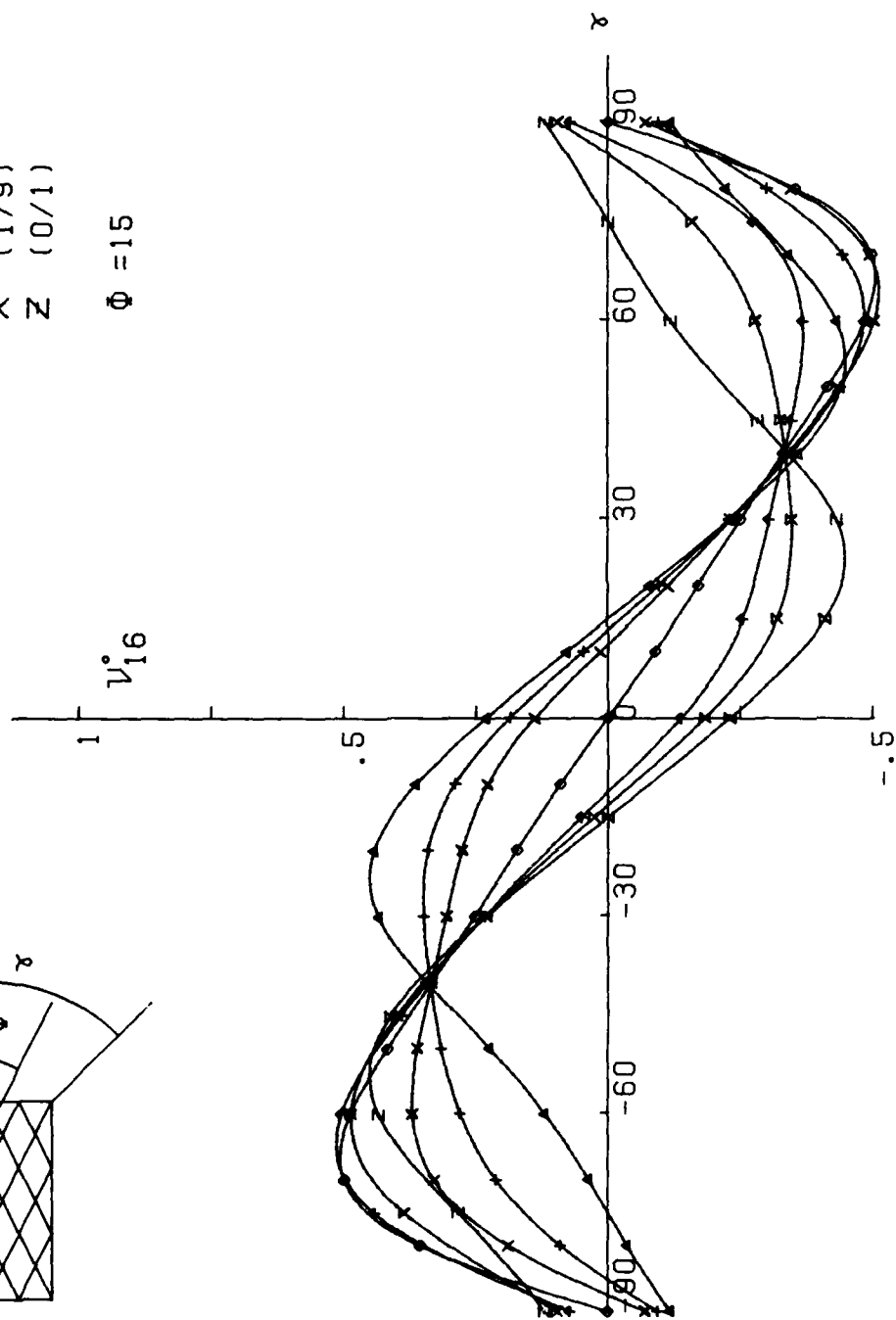


FIG.:268

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Z (0/1)
 $\Phi = 30$

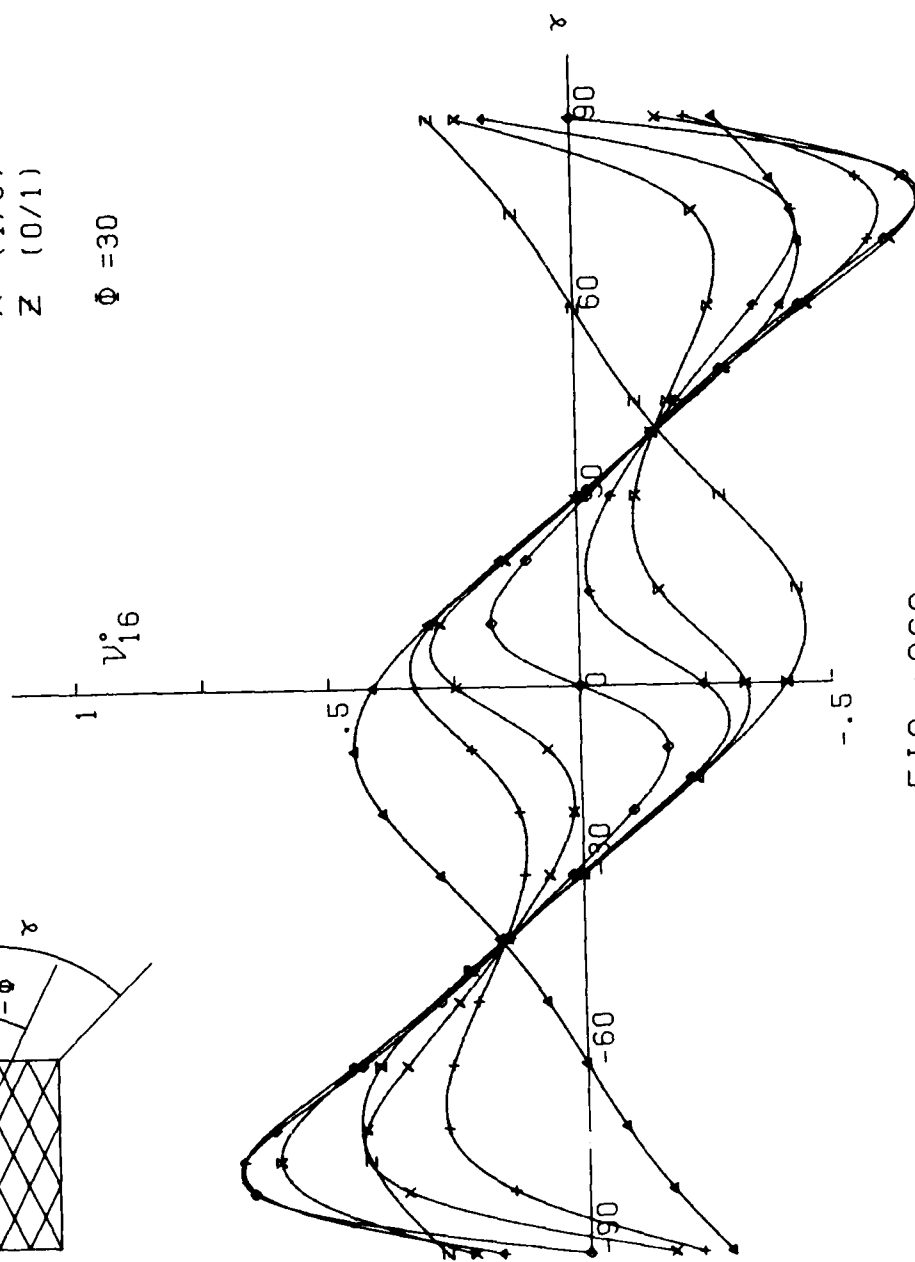
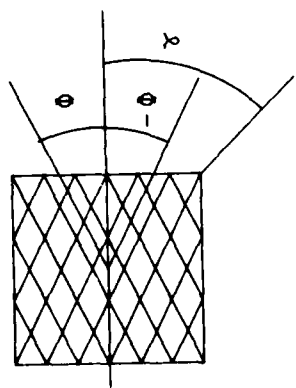
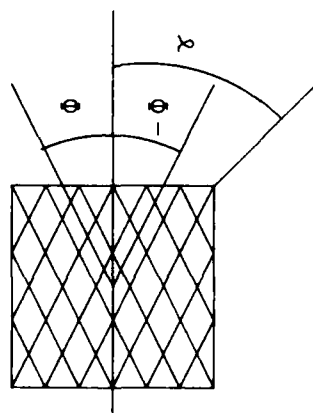


FIG.:269



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 \times (0/1)
 $\Phi = 45$

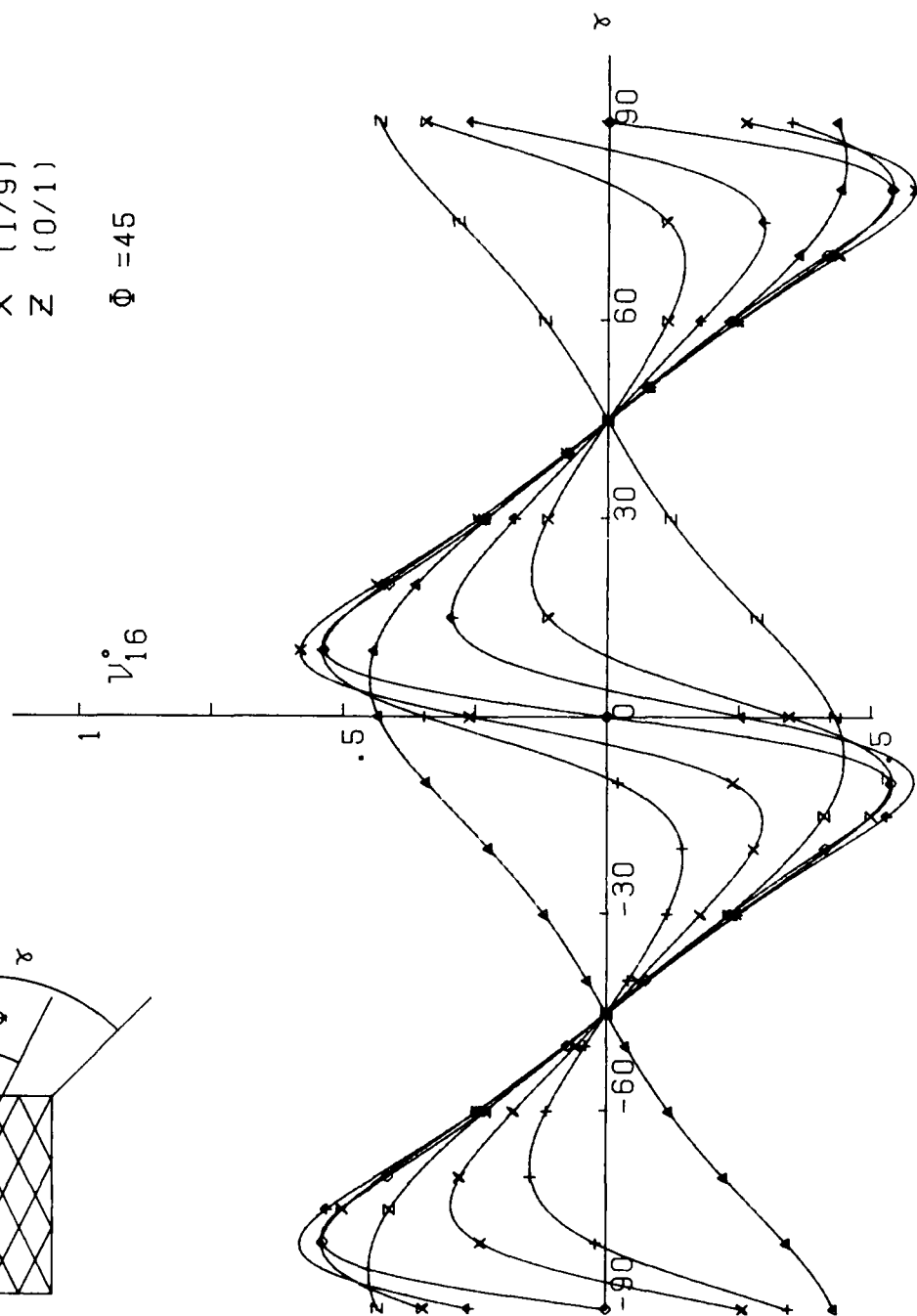


FIG.: 270

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\Phi = 60$

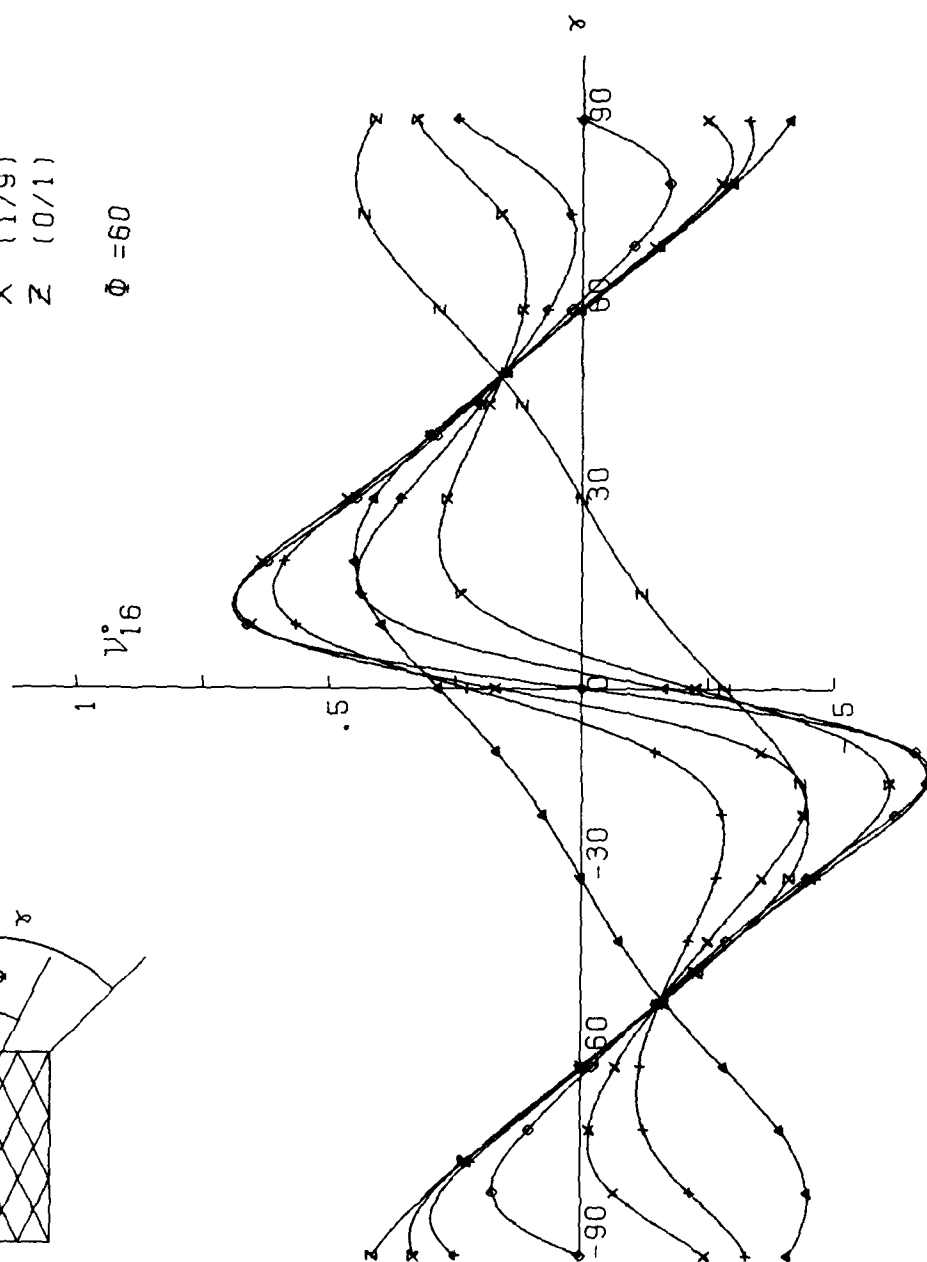
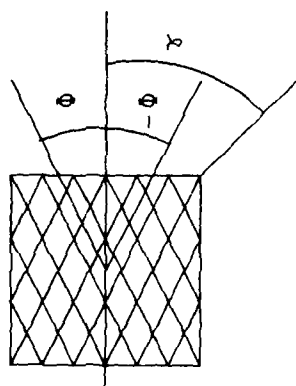


FIG.: 271

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)
 $\Phi = 75$

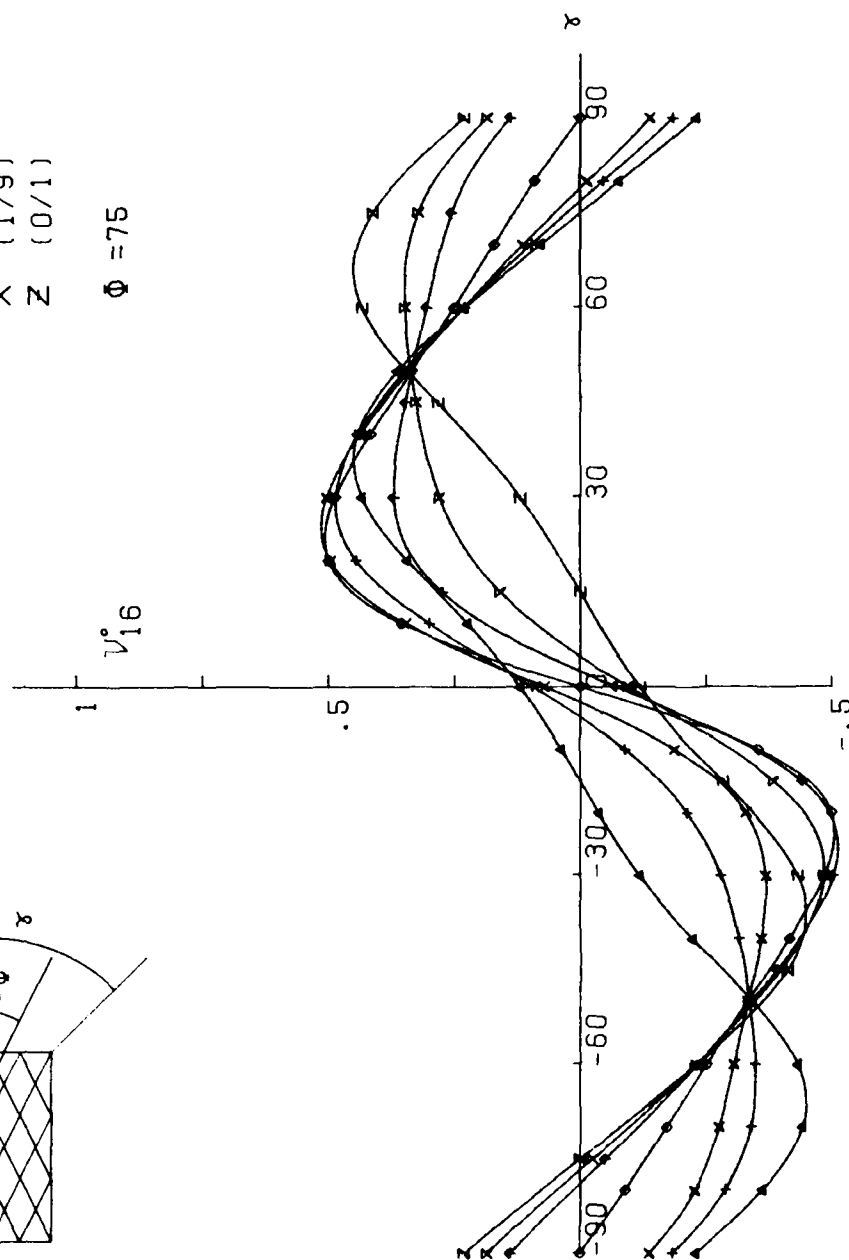
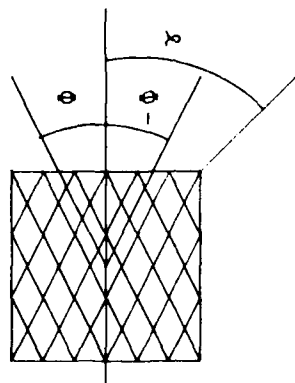


FIG.:272

Φ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\chi = -75$

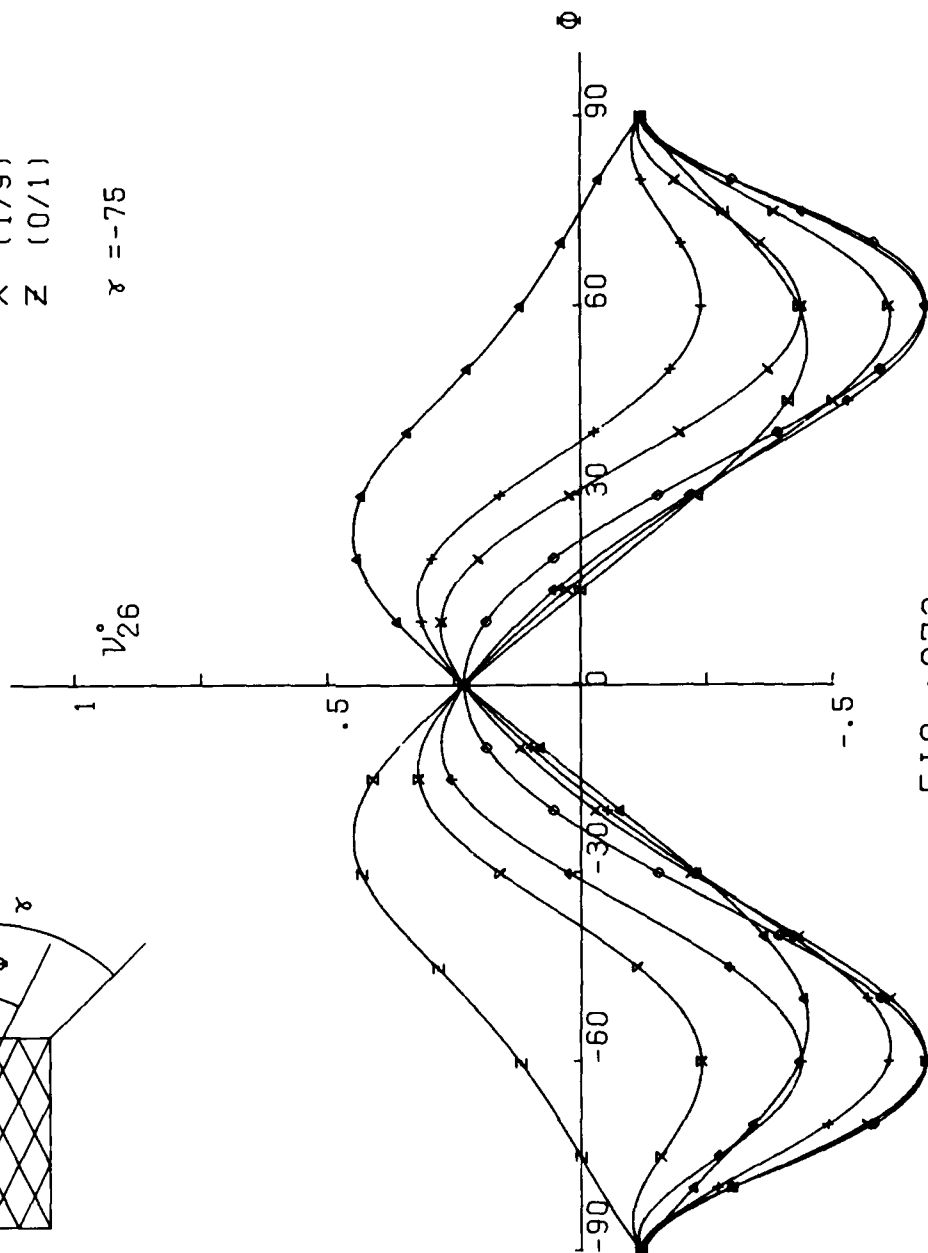
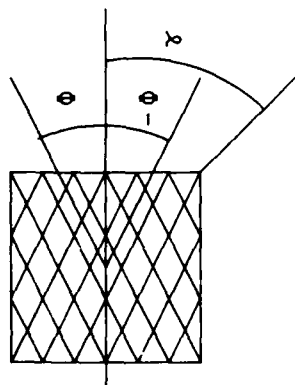


FIG.:273

Φ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = -60$

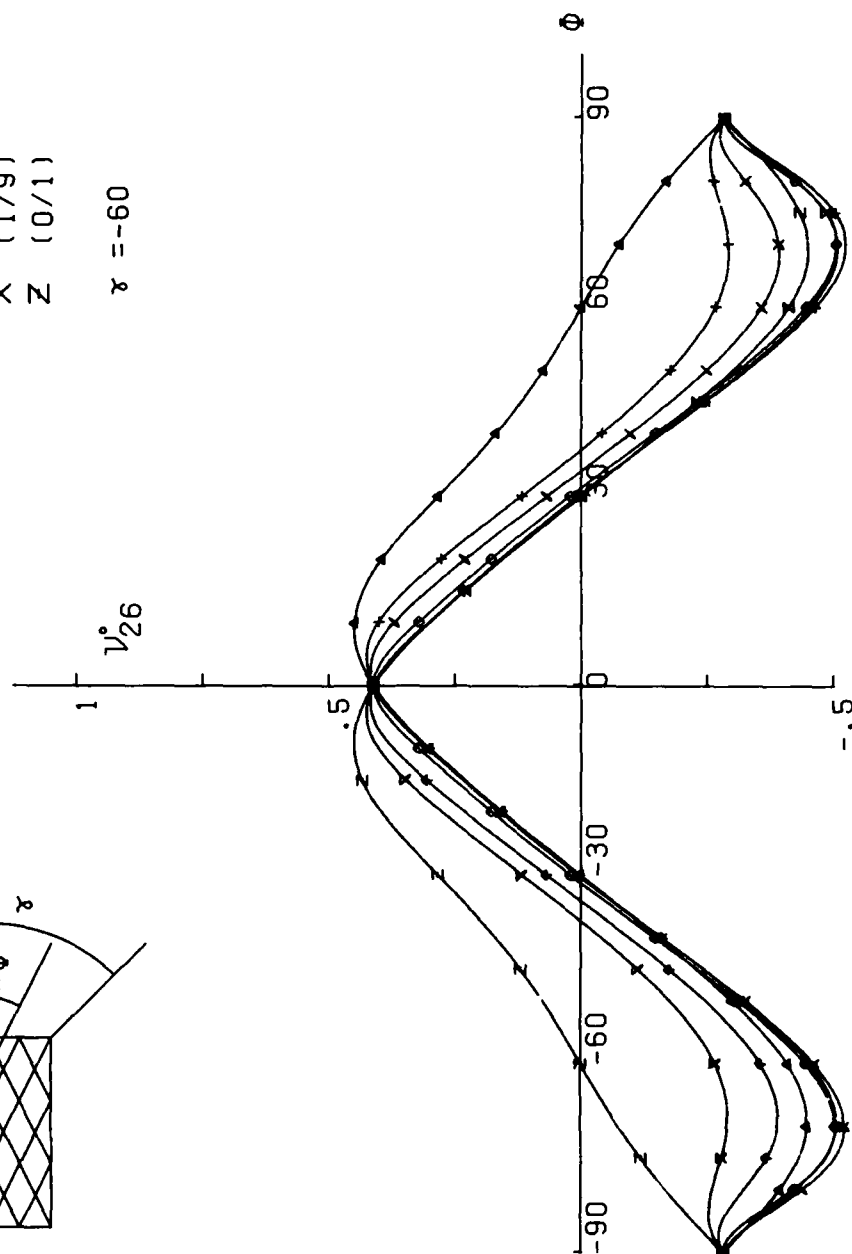
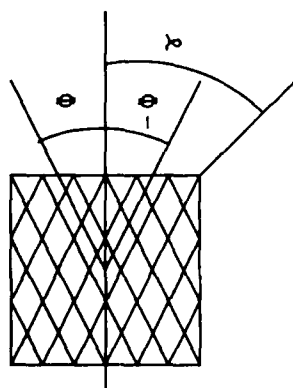


FIG.:274

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\chi = -45$

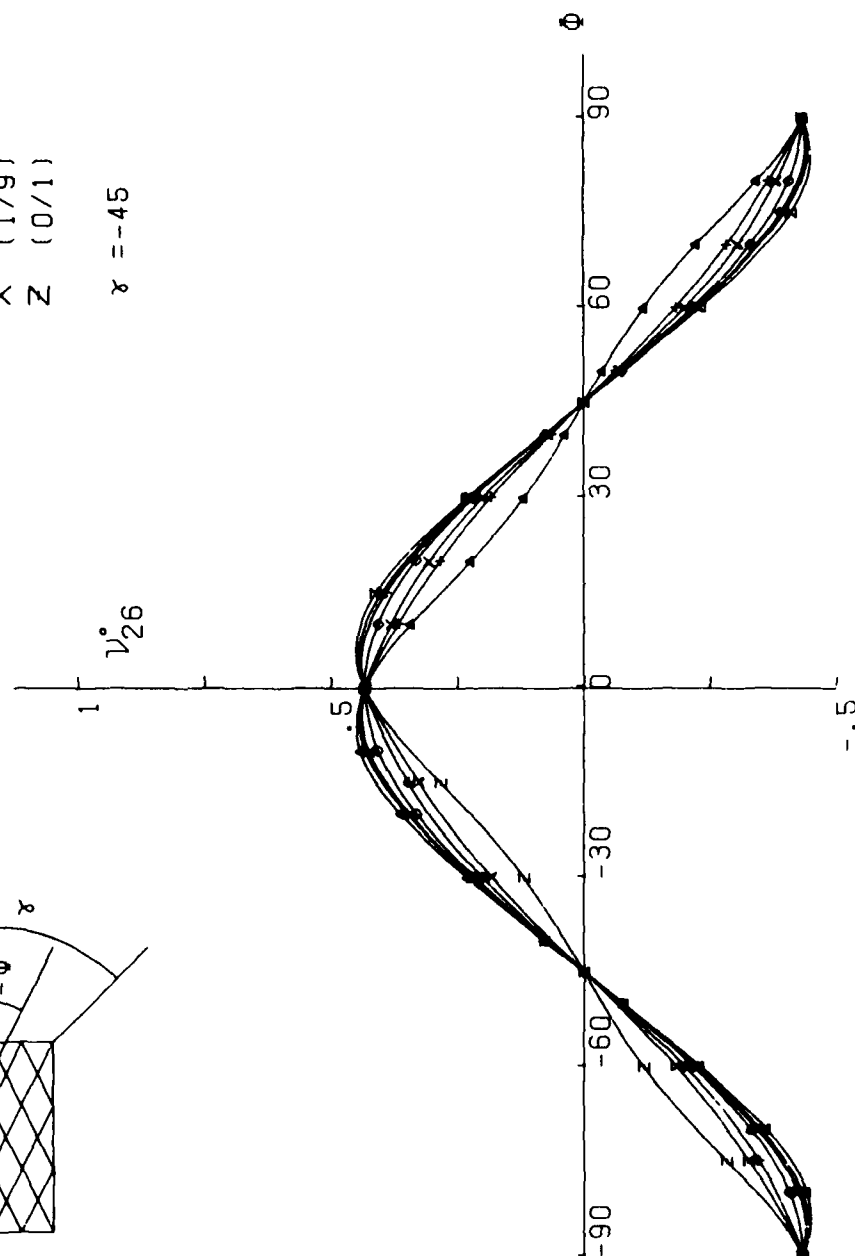
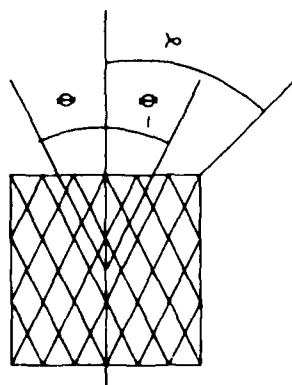


FIG.: 275

Φ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\chi = -30$

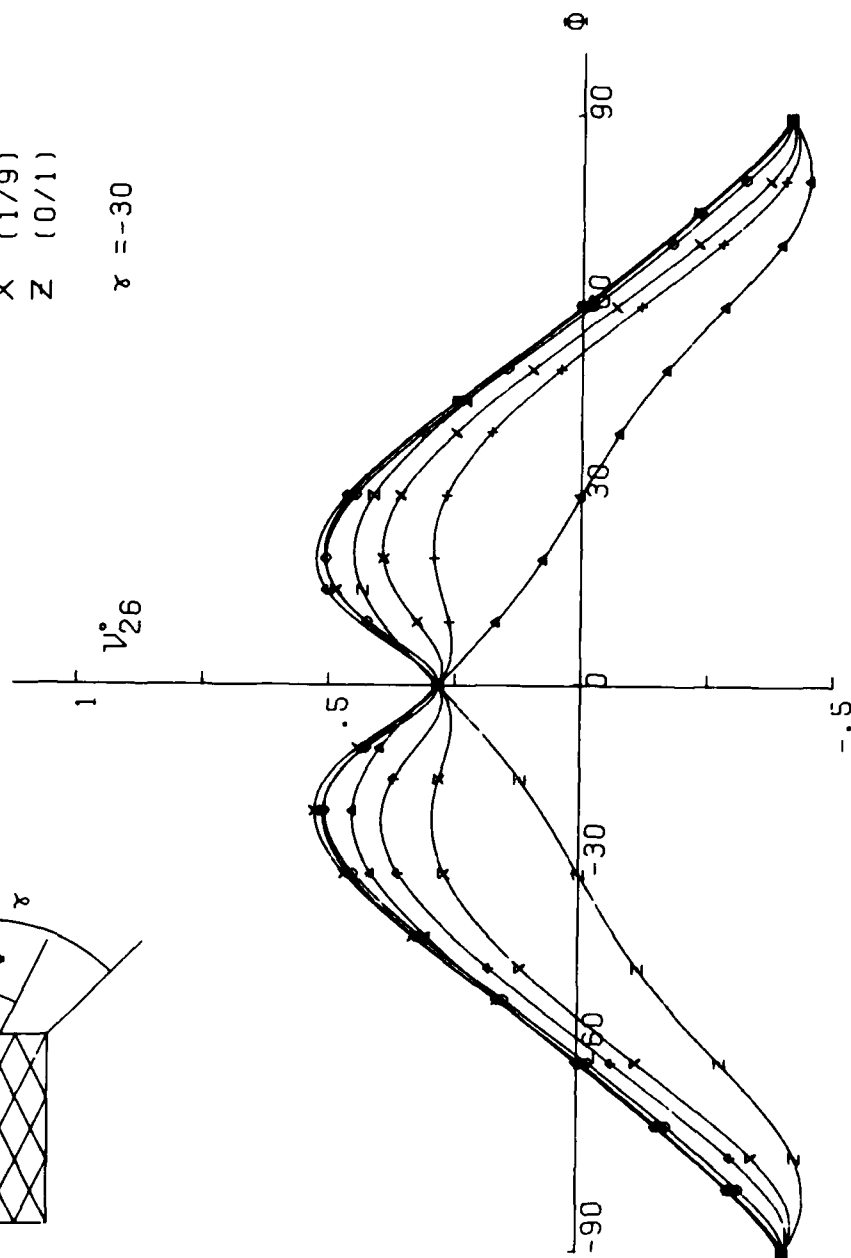
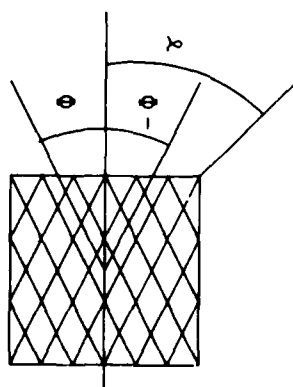
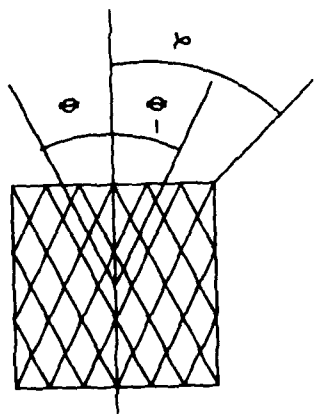


FIG.: 276



$\phi / -\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Σ (0/1)
 $\gamma = -15$

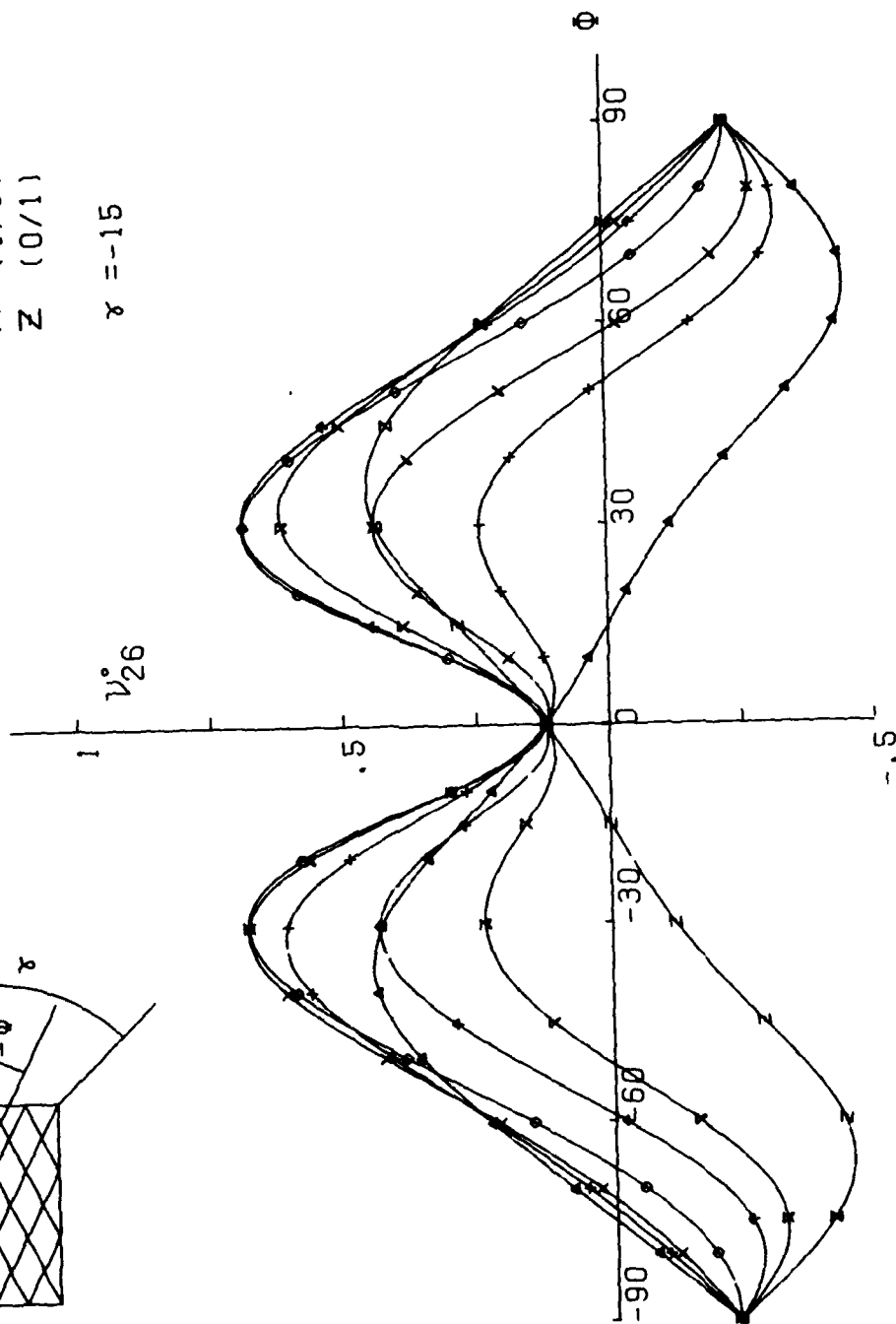
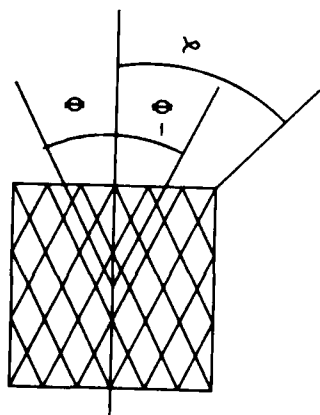


FIG.:277



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\chi = 0$

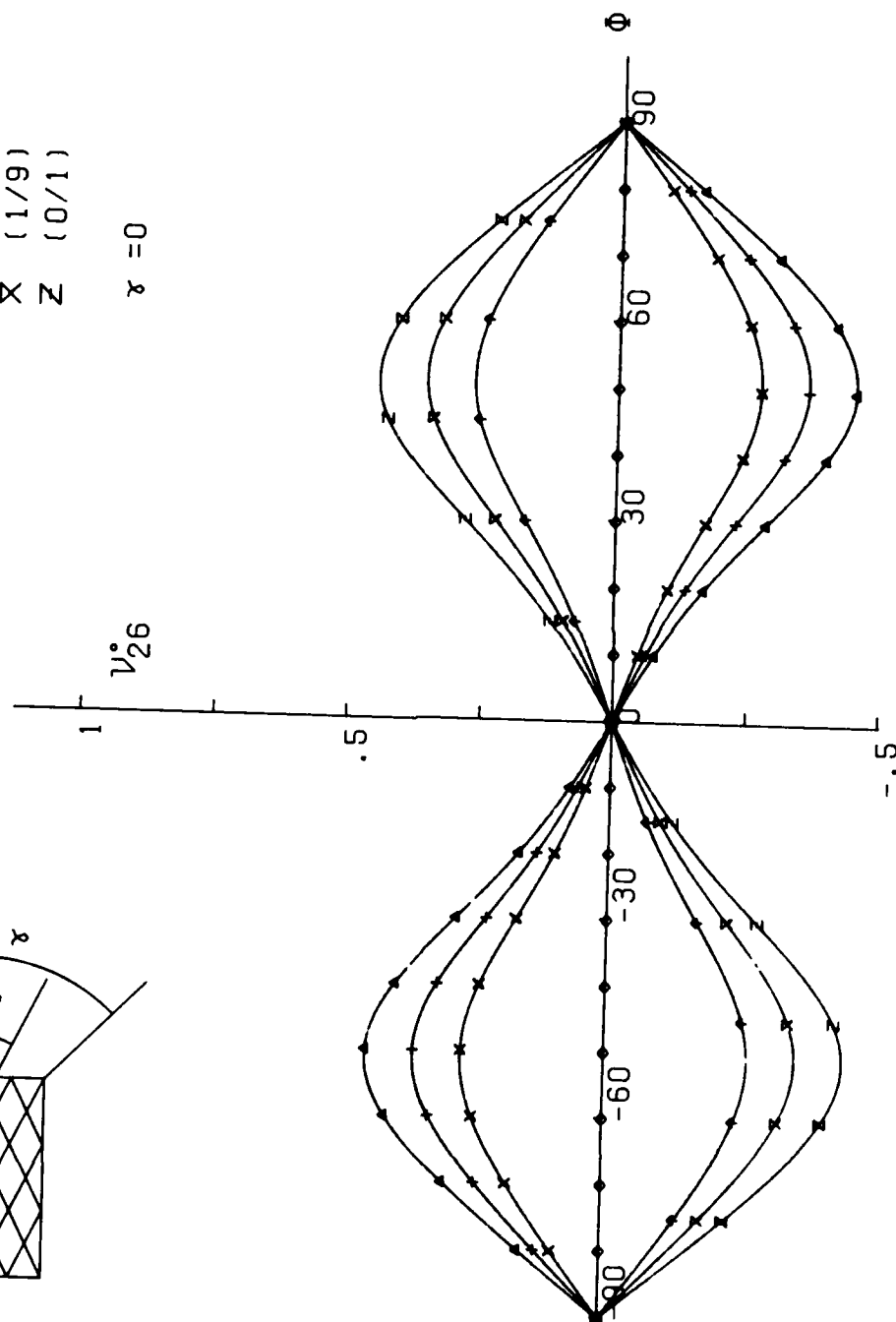
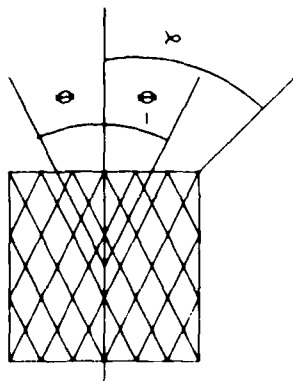


FIG.:278



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\gamma = 15$

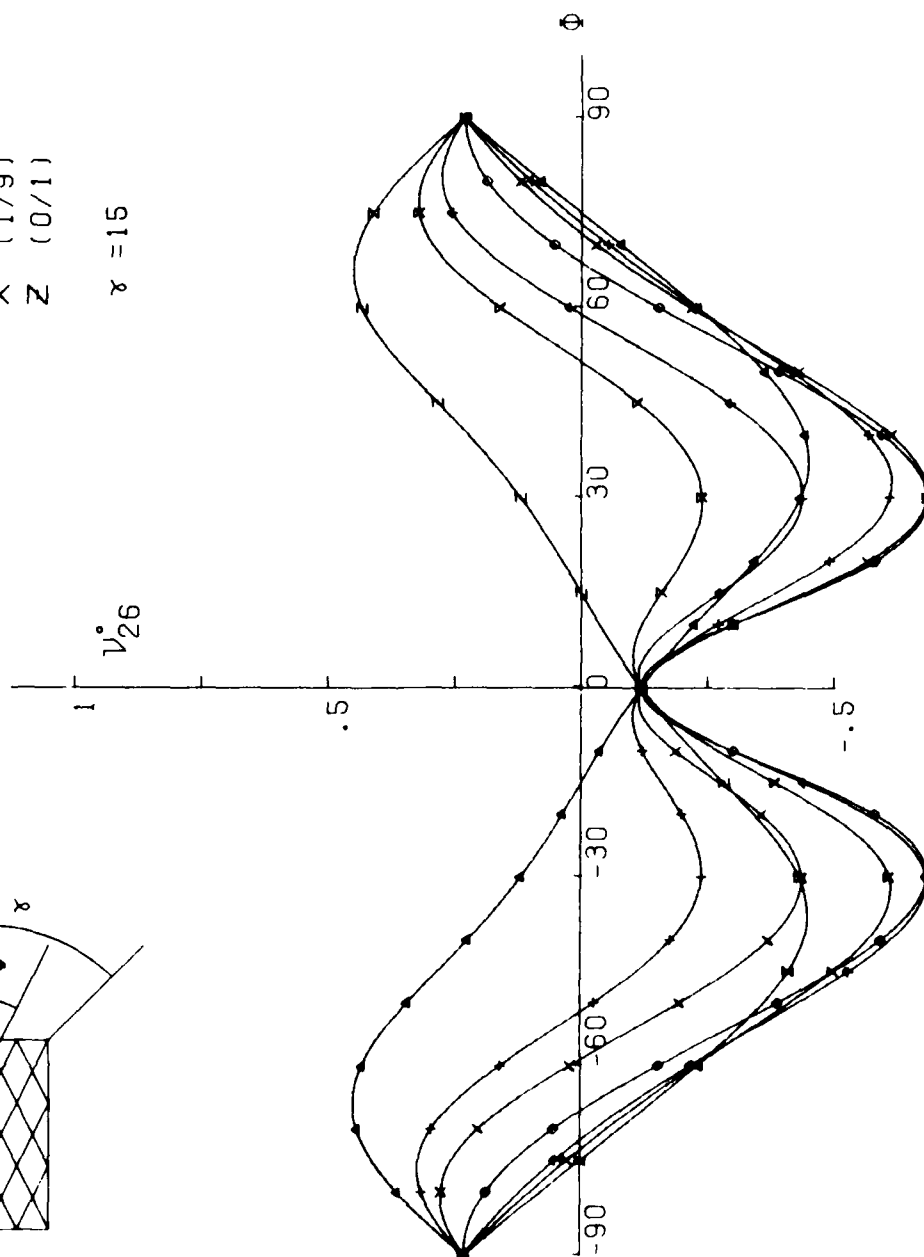
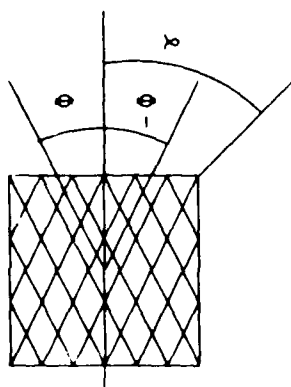


FIG.:279



$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Z (0/1)

$\gamma = 30$

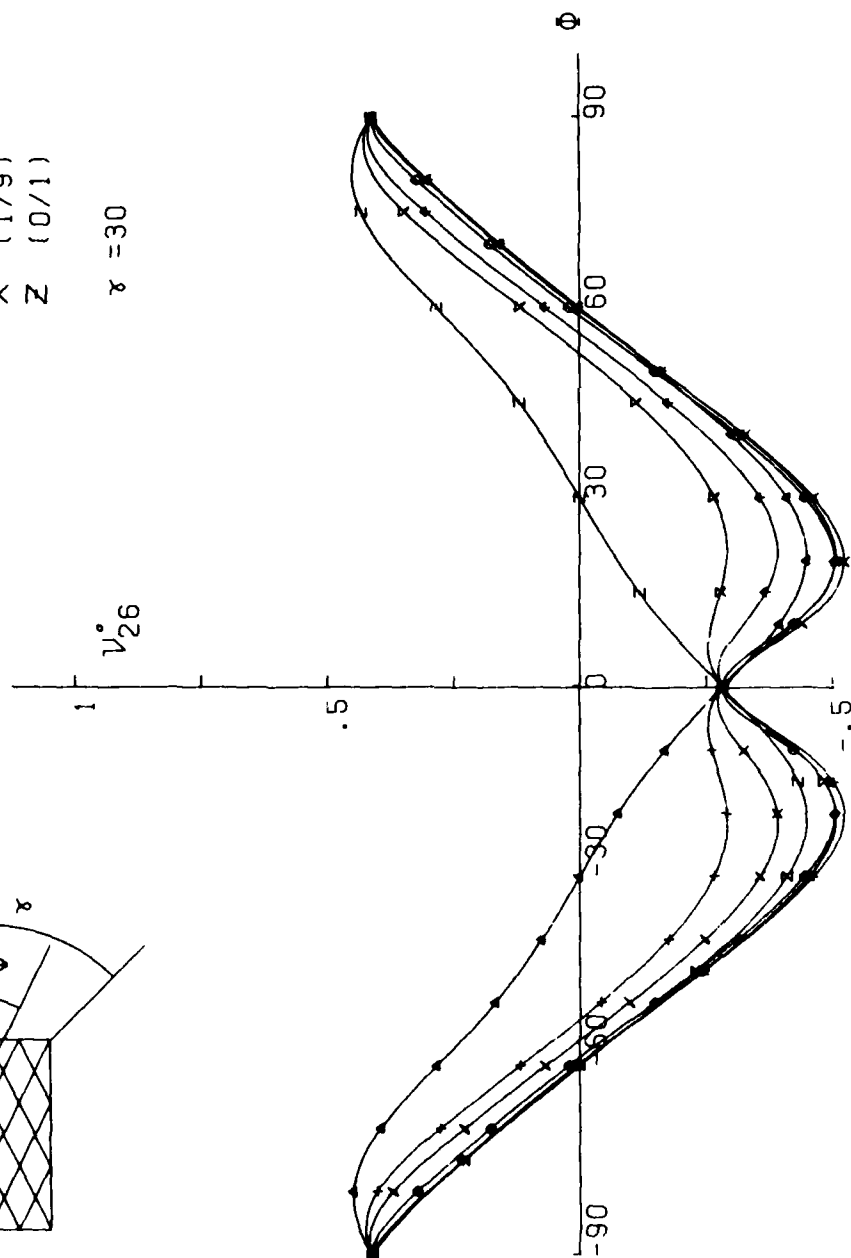
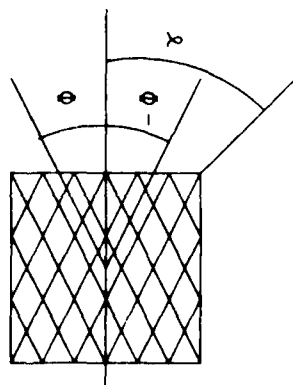


FIG.: 280



ϕ/Φ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 Σ (1/9)
 Z (0/1)
 $\gamma = 45$

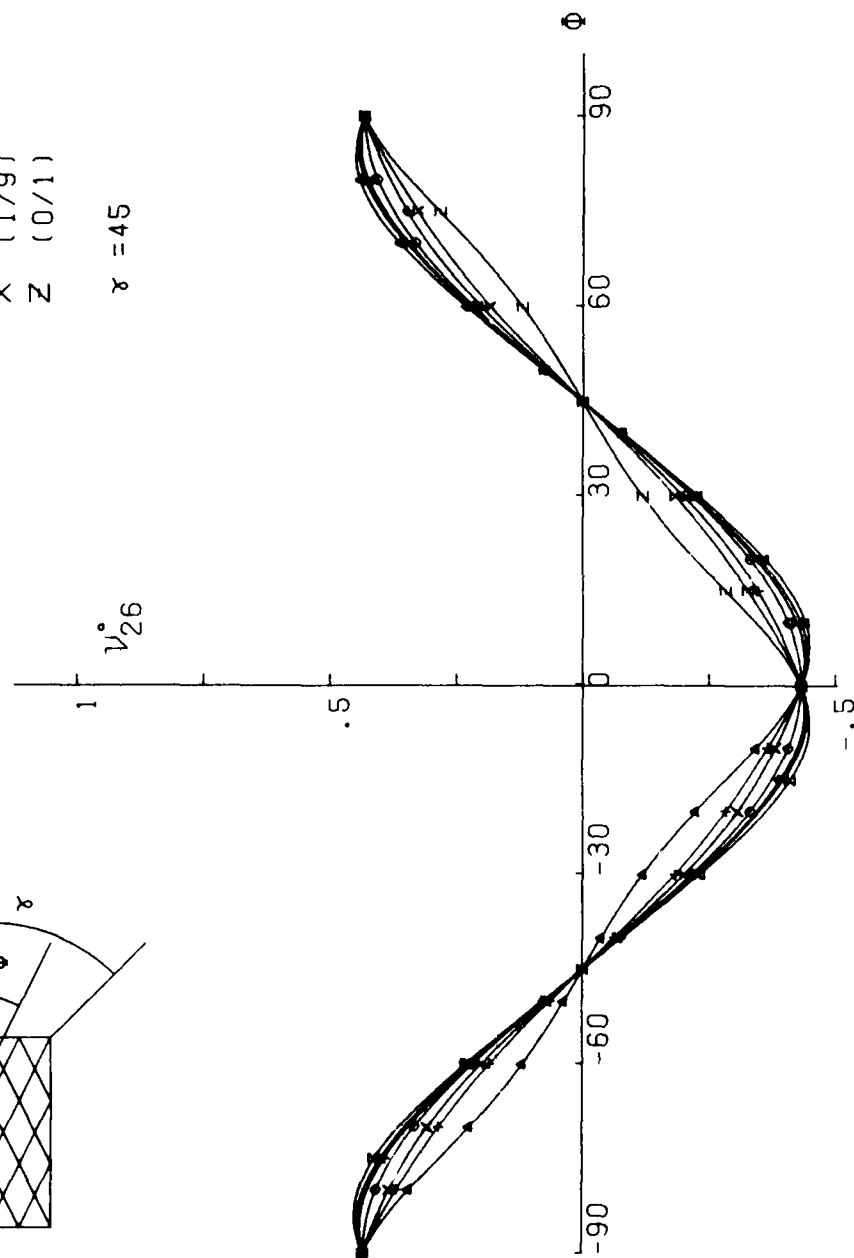


FIG.:281

$\Phi / -\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 z (0/1)

$\gamma = 60$

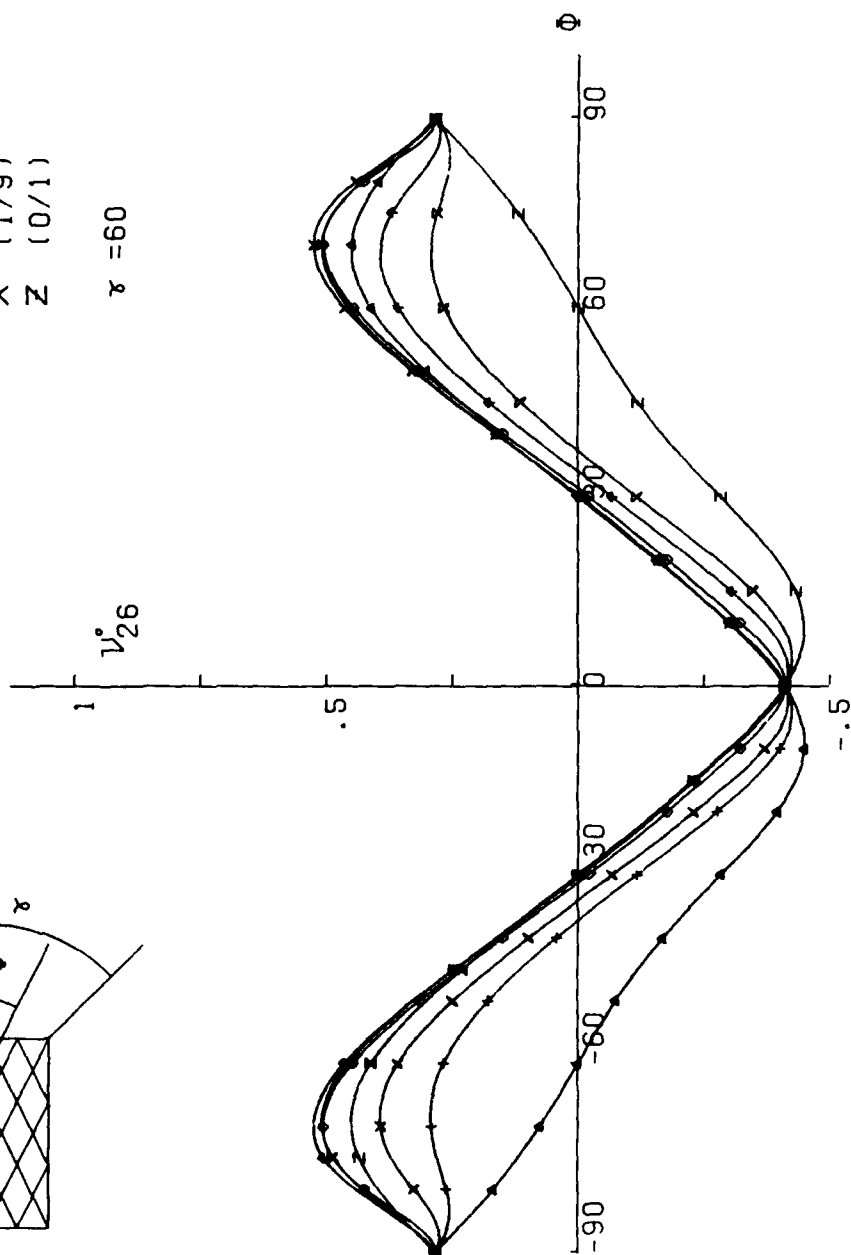
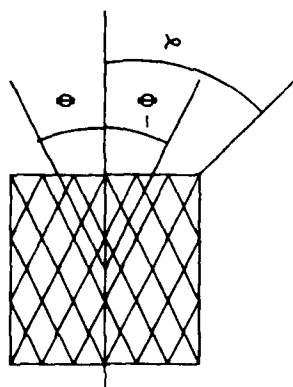
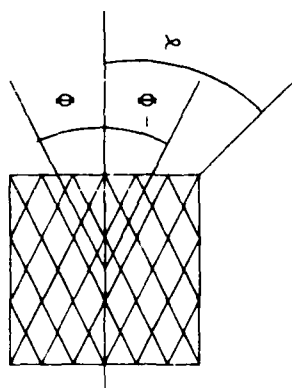


FIG.:282



$\phi / -\phi$

Δ	(1/0)
+	(9/1)
X	(4/1)
\diamond	(1/1)
\oplus	(1/4)
\times	(1/9)
Z	(0/1)

$\chi = 75^\circ$

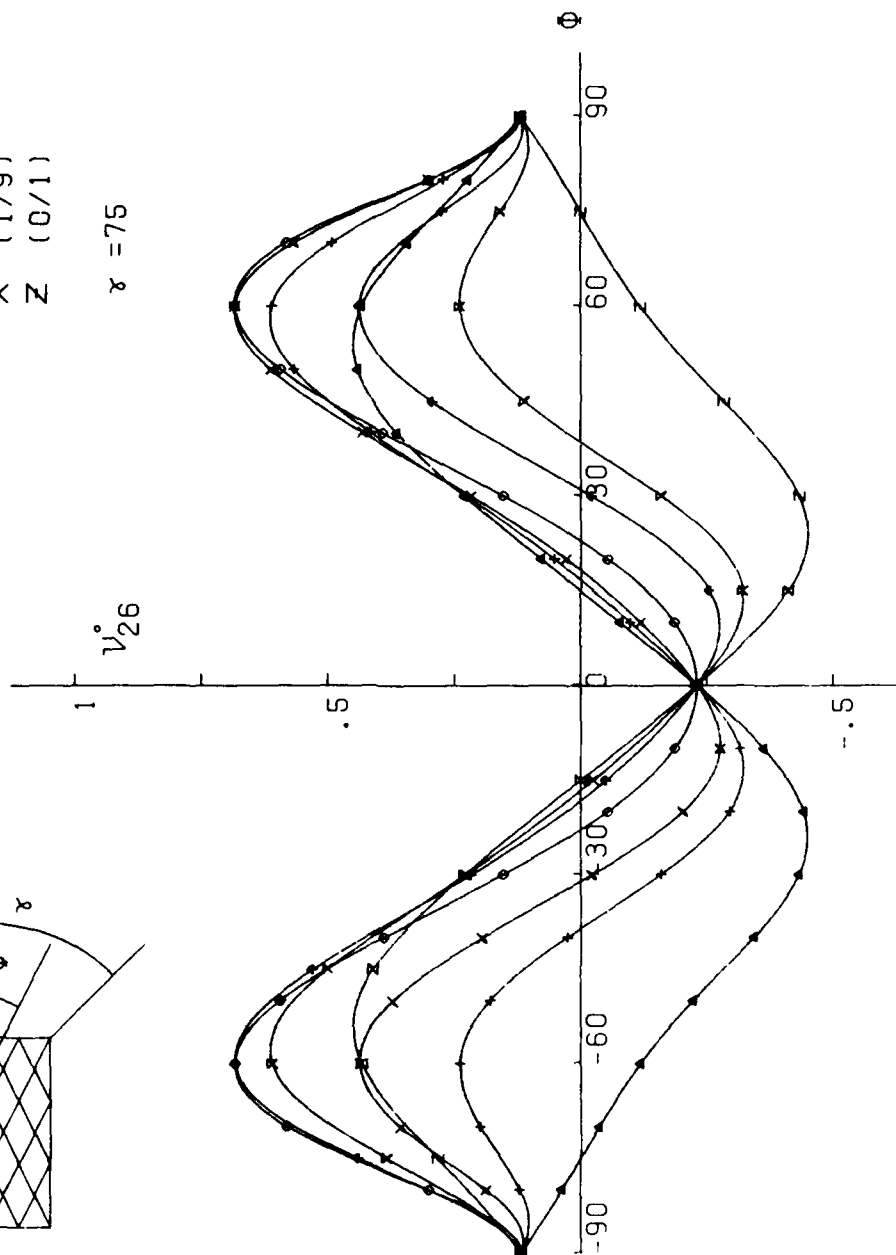


FIG.: 283

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 ∇ (0/1)
 $\Phi = 15$

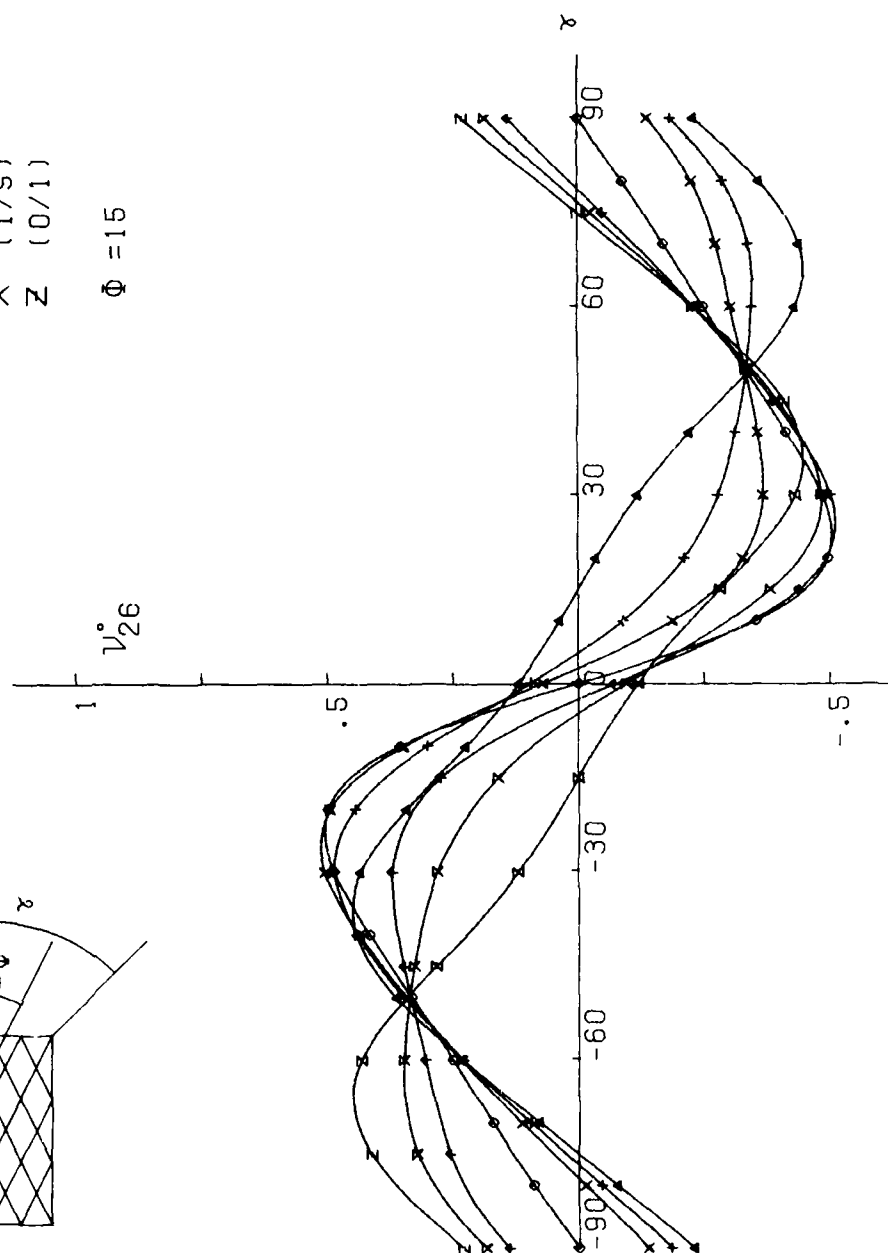
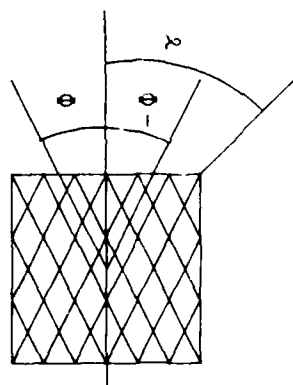


FIG.: 284

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\Phi = 30$

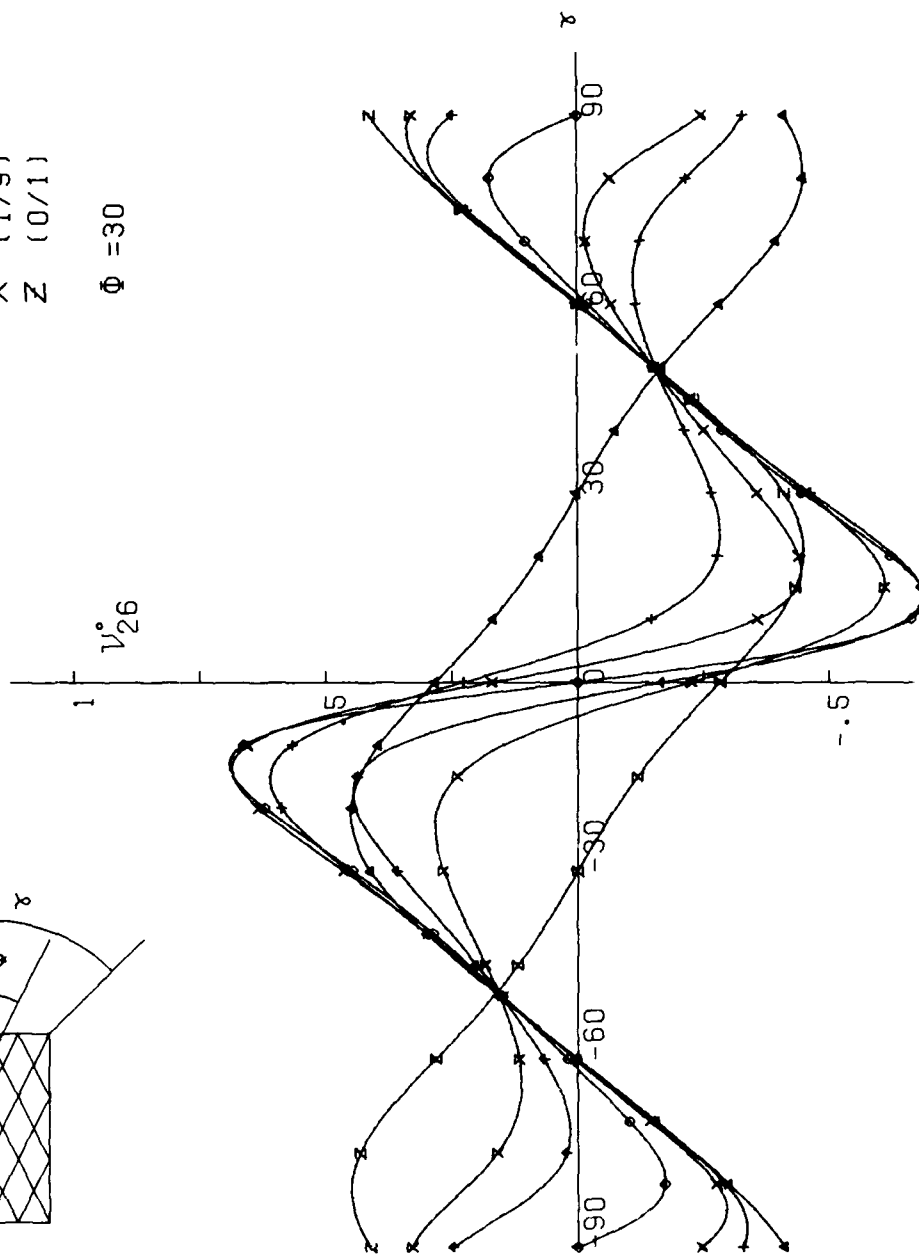
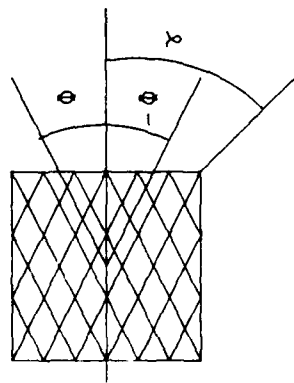
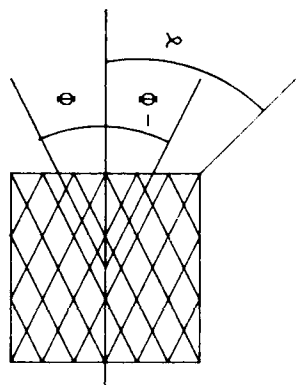


FIG.: 285



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)
 $\Phi = 45$

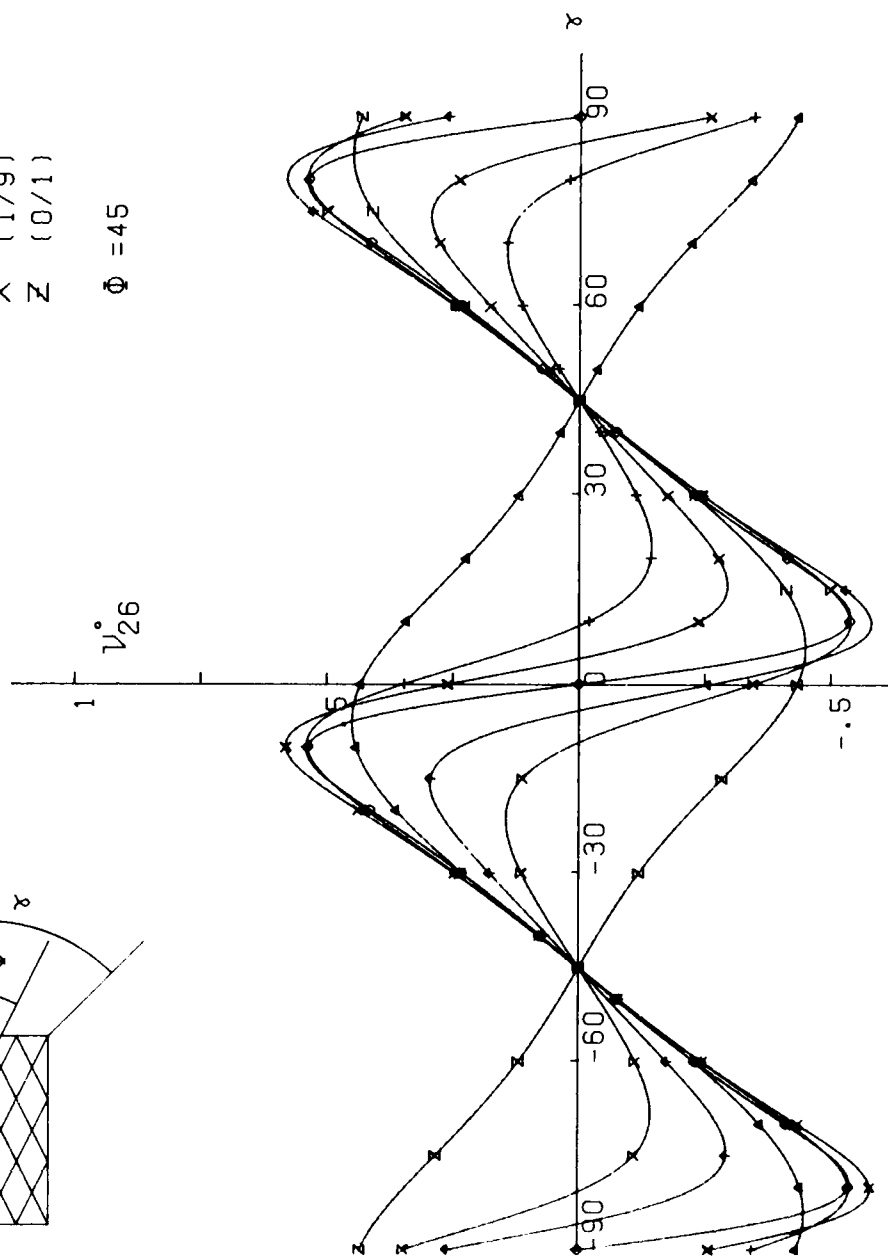


FIG.:286

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 Σ (0/1)
 $\Phi = 60$

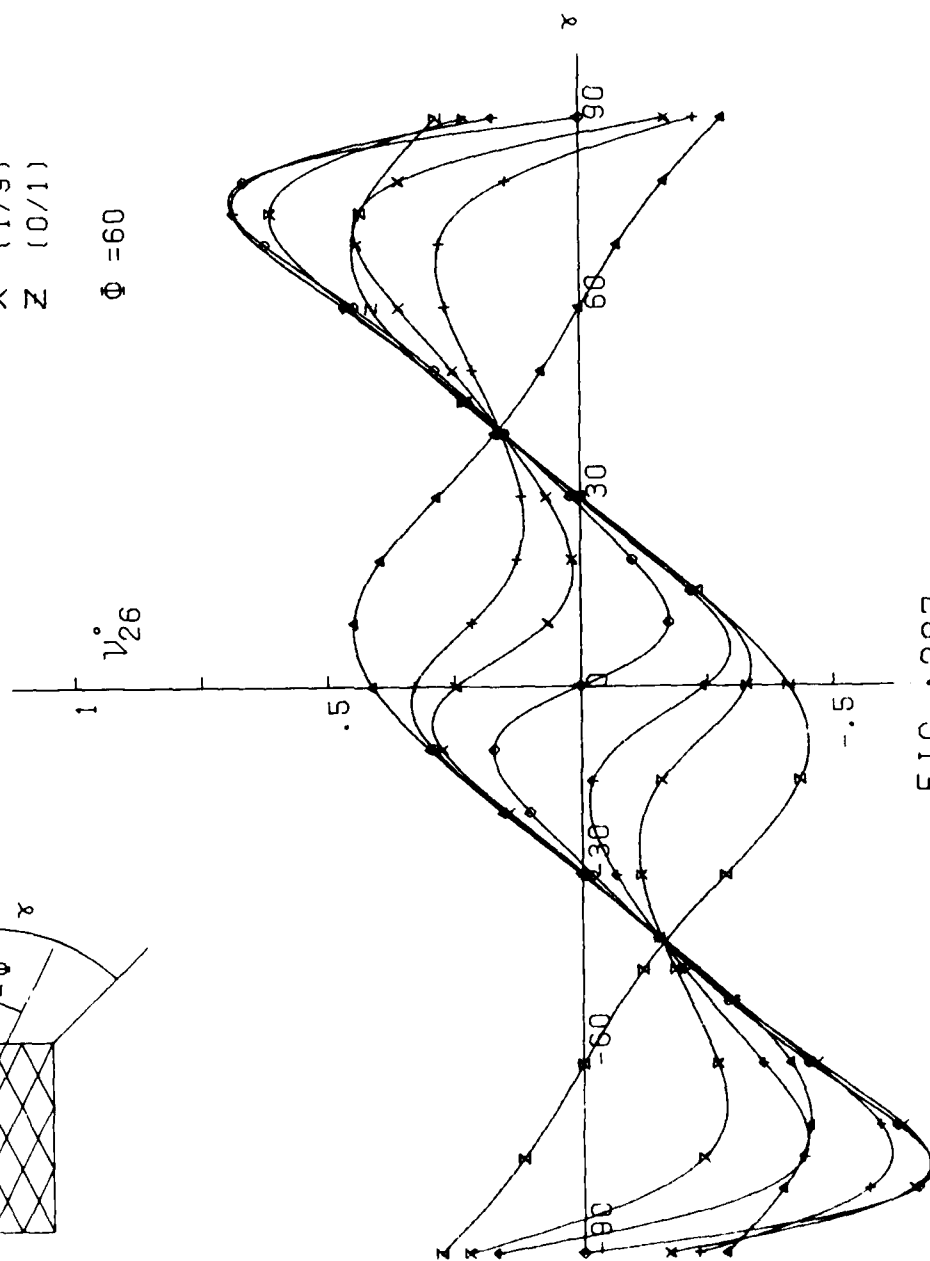
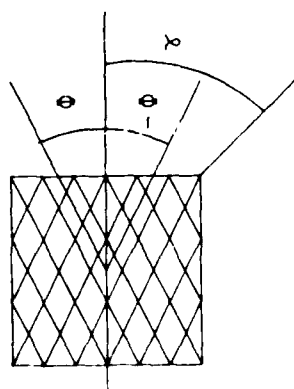
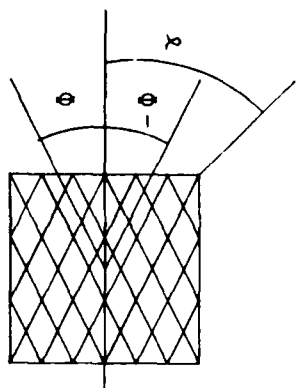


FIG.:287



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\phi = 75$

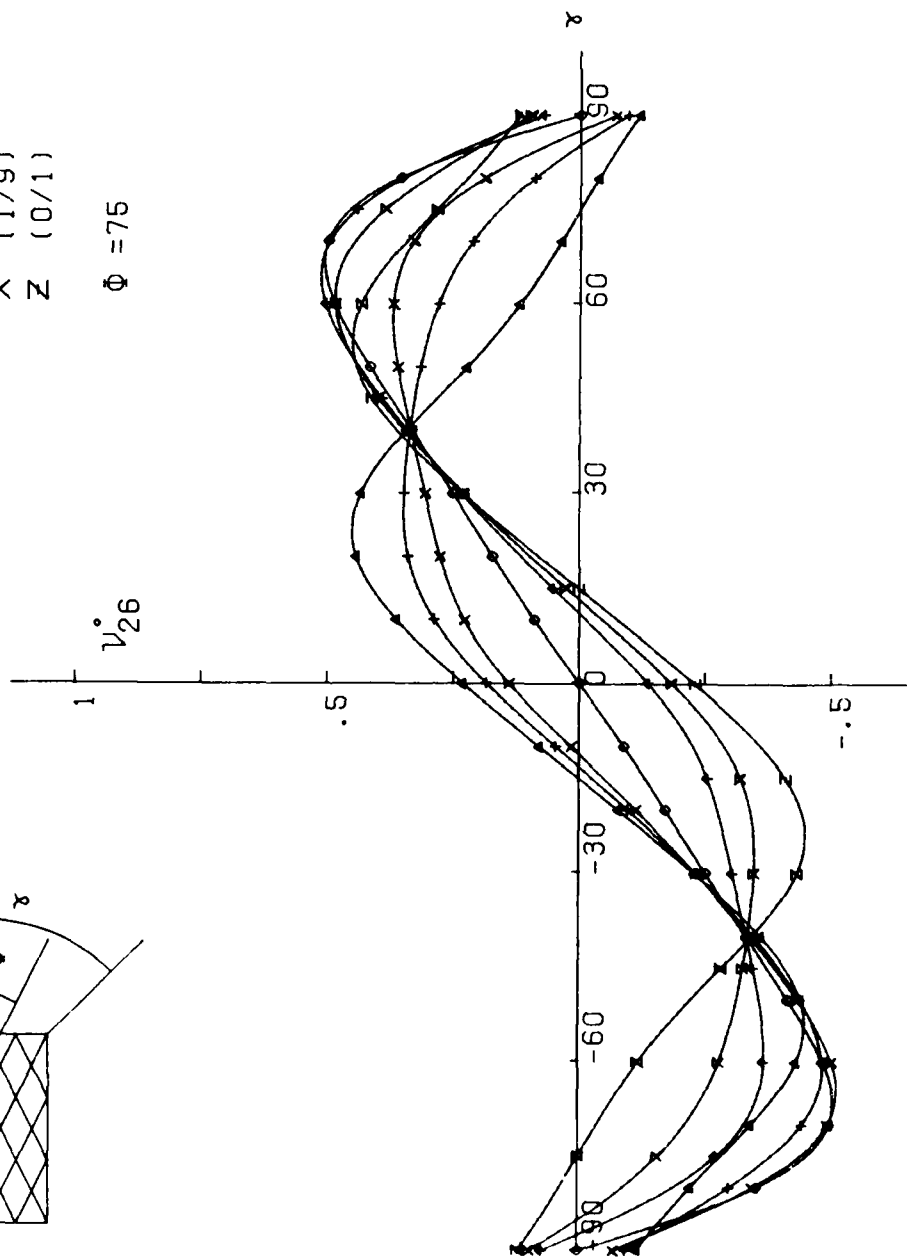
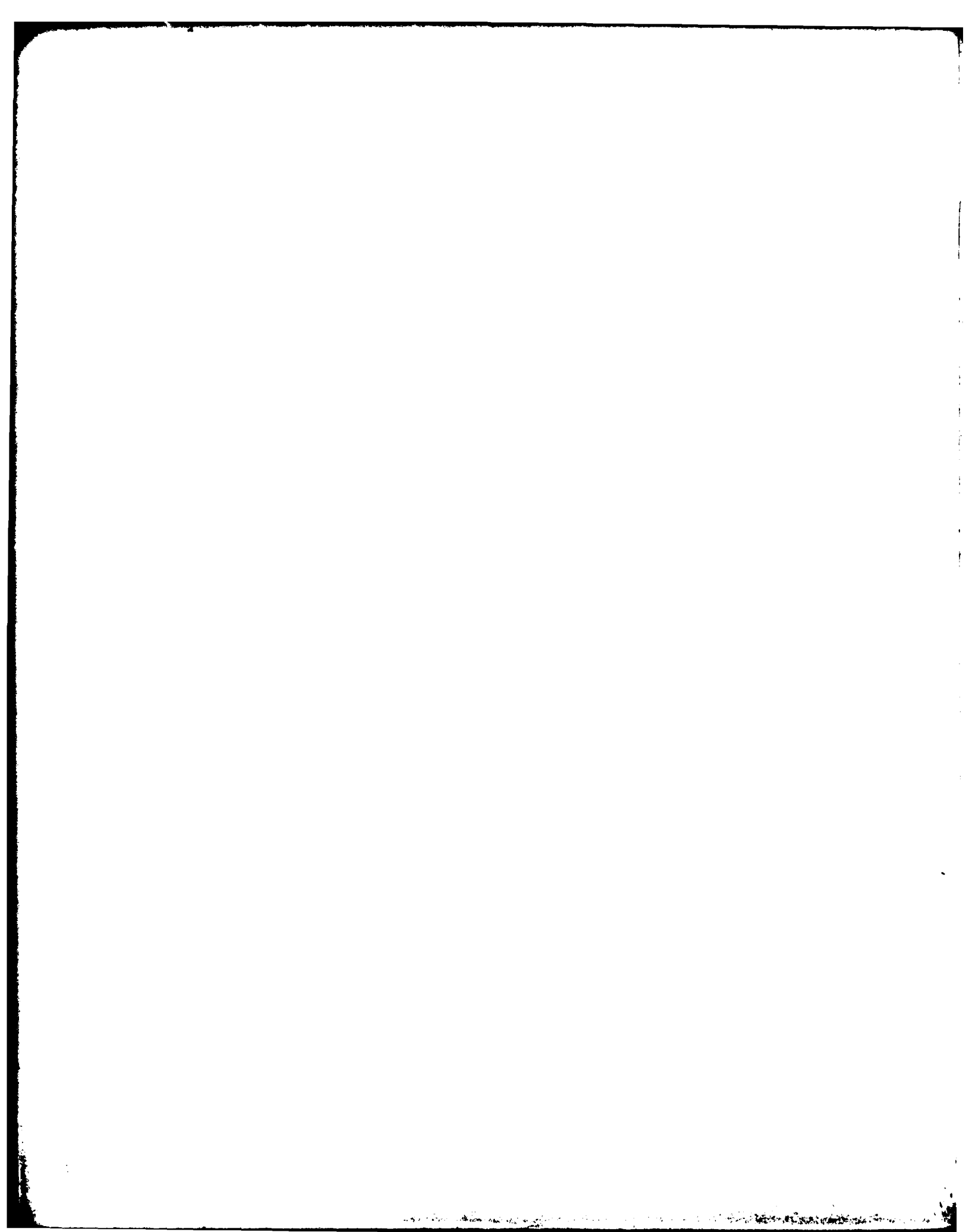


FIG.:288



YOUNG'S MODULI, SHEAR MODULUS AND
THEIR RATIOS

PARAMETER	FIGURE NOS.
E_1	289-304
E_2	305-320
E_6	321-336
E_1/E_2	337-352
E_1/E_6	353-368
E_2/E_6	369-384

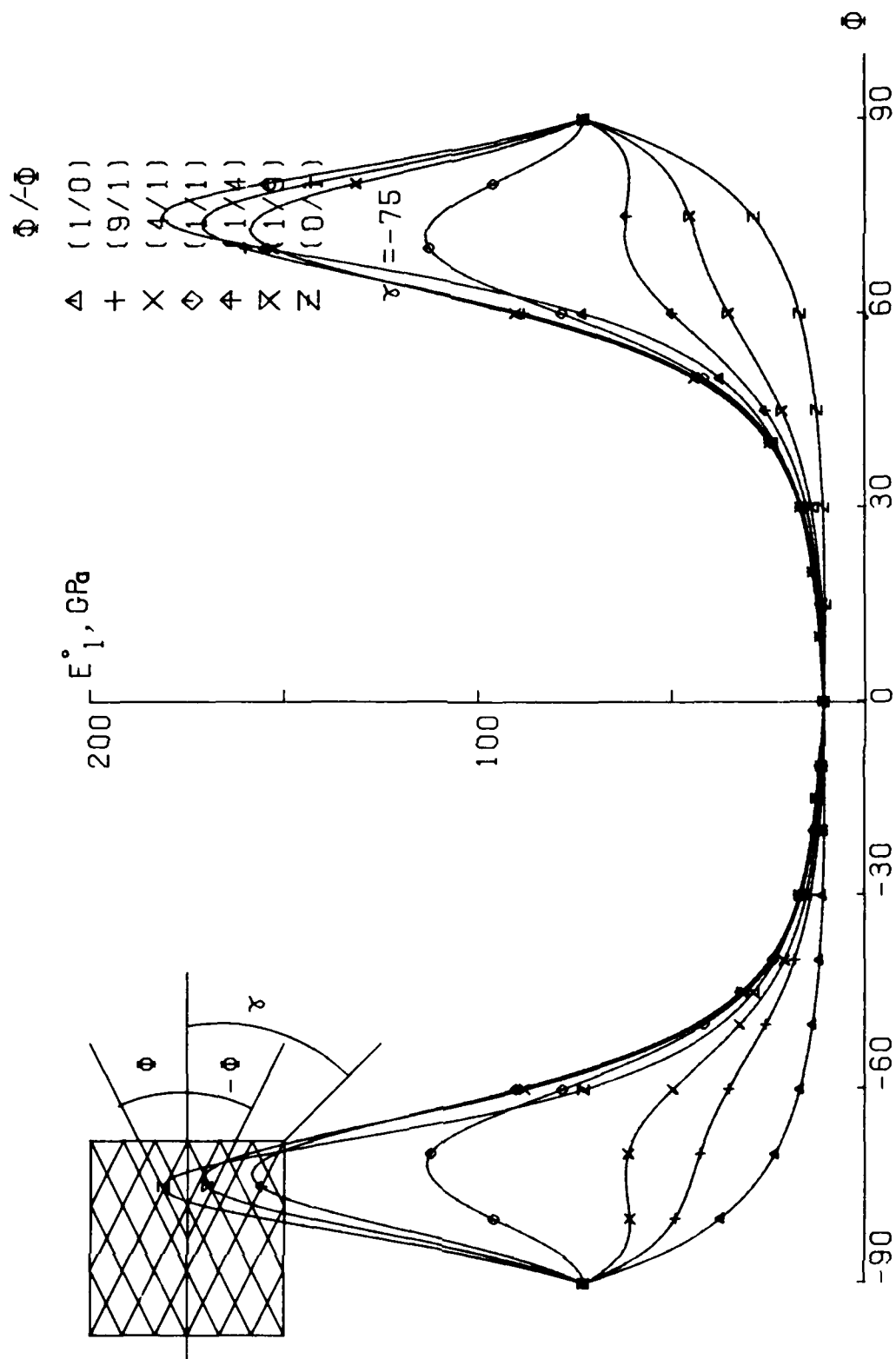


FIG.: 289

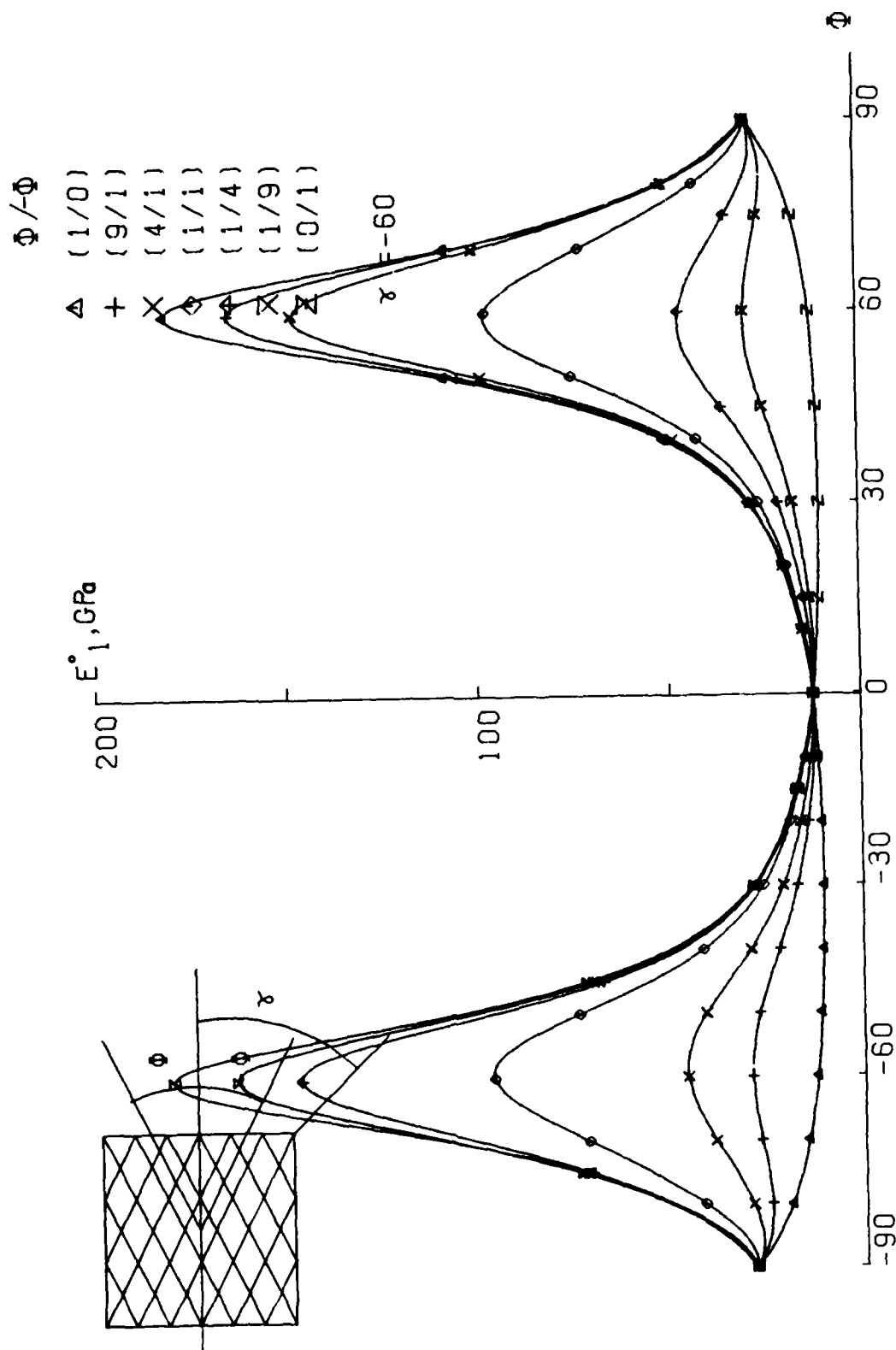


FIG.:290

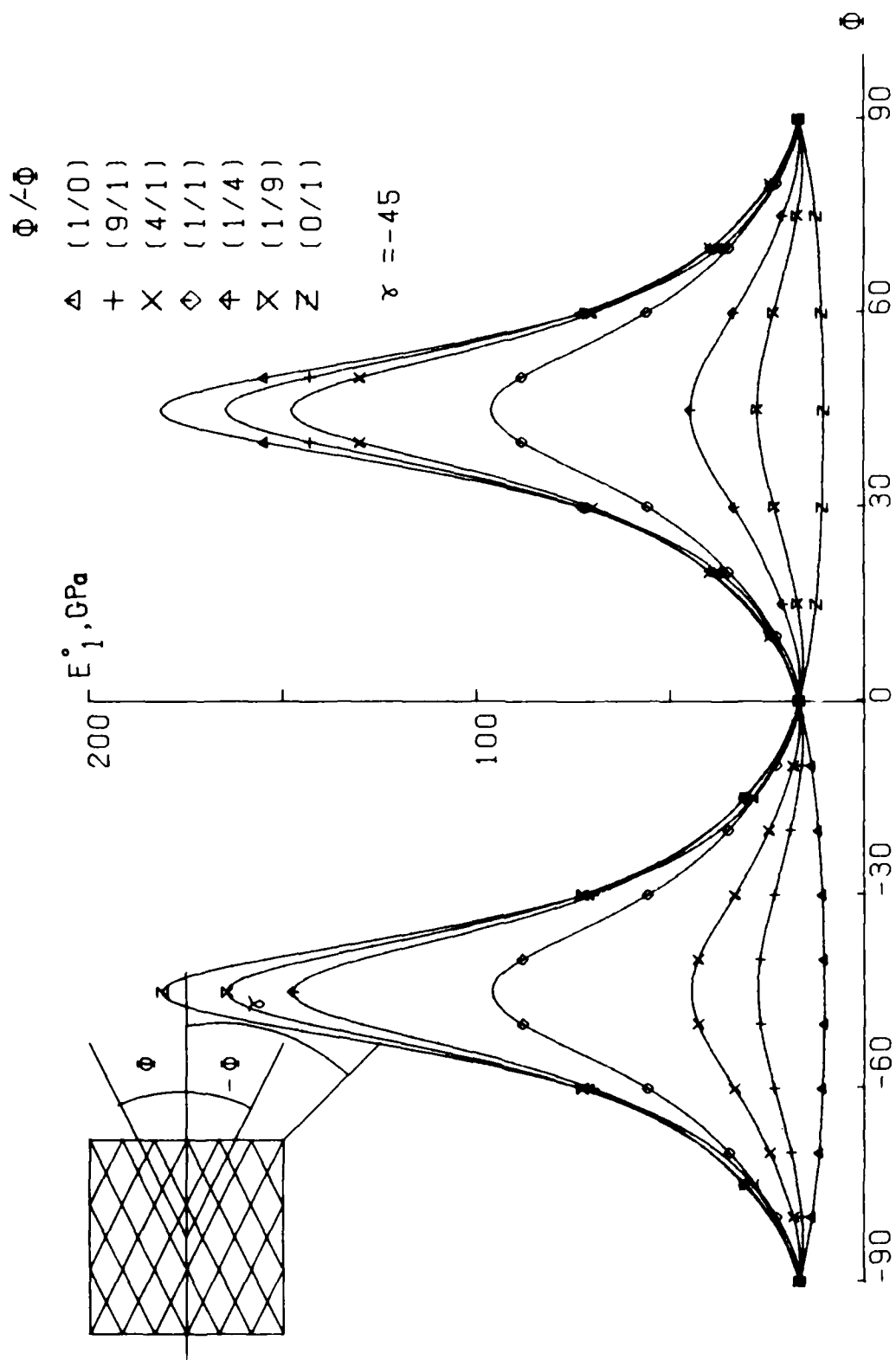


FIG.:291

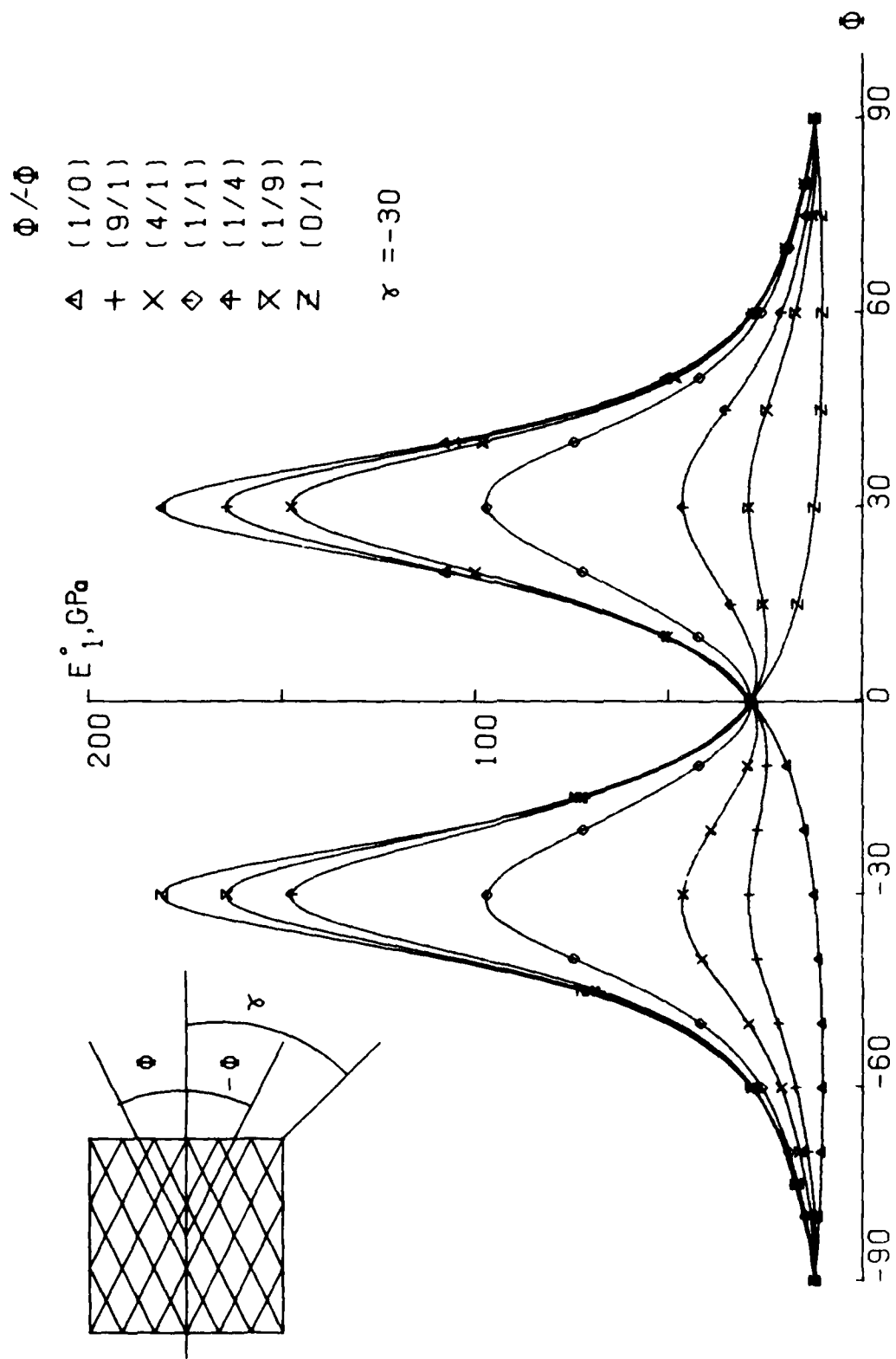


FIG.:292

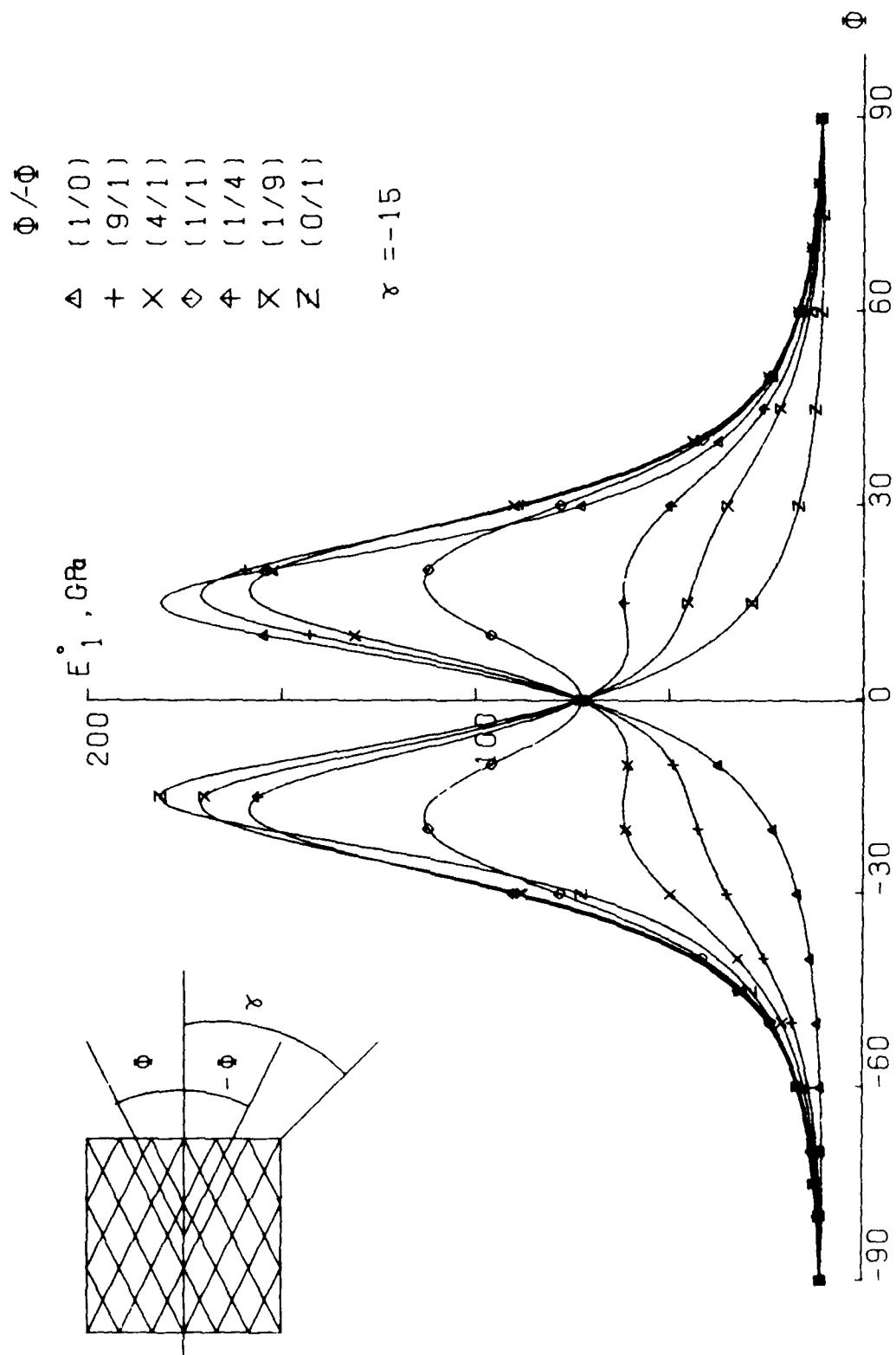


FIG.: 293

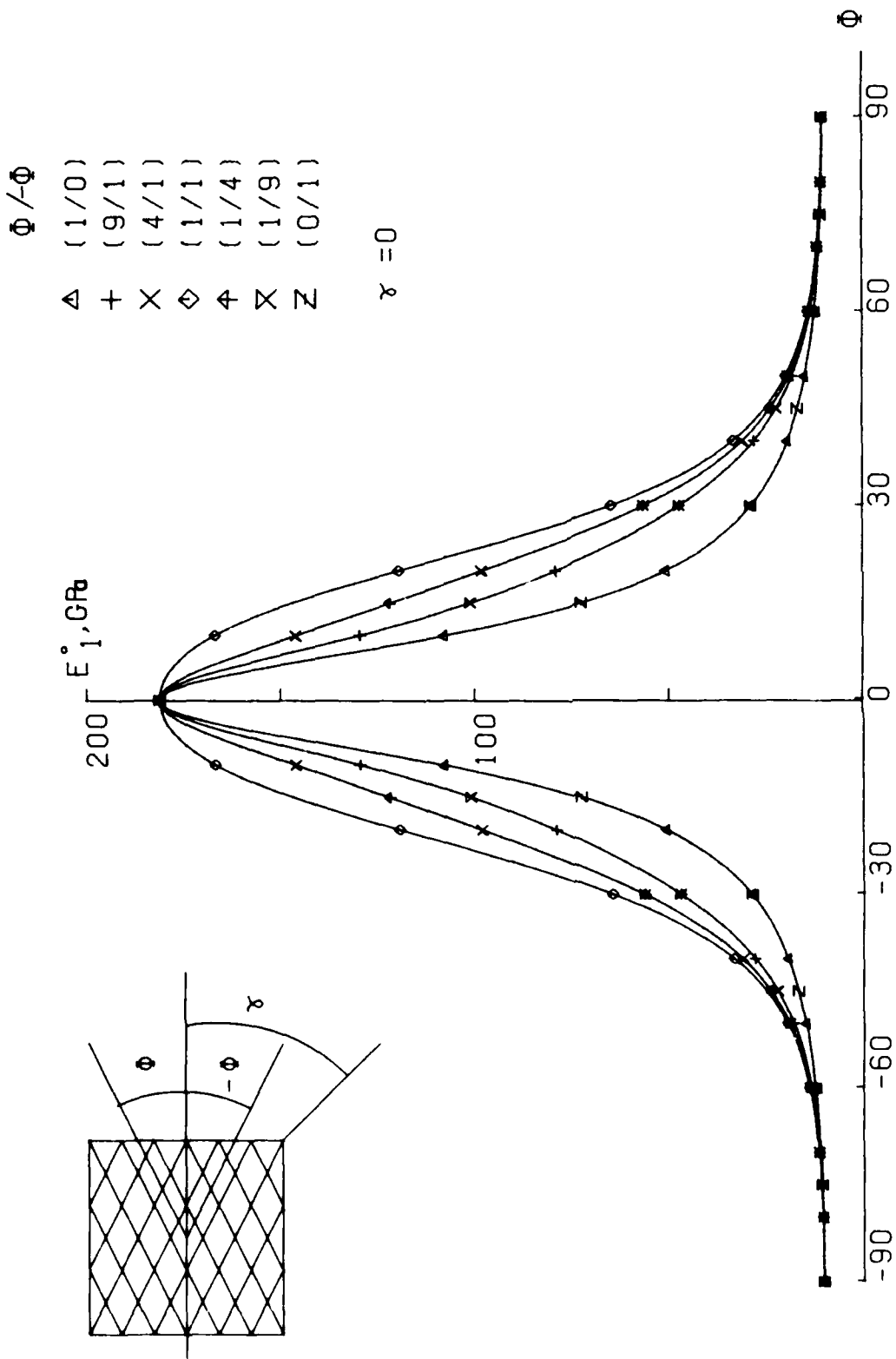


FIG.: 294

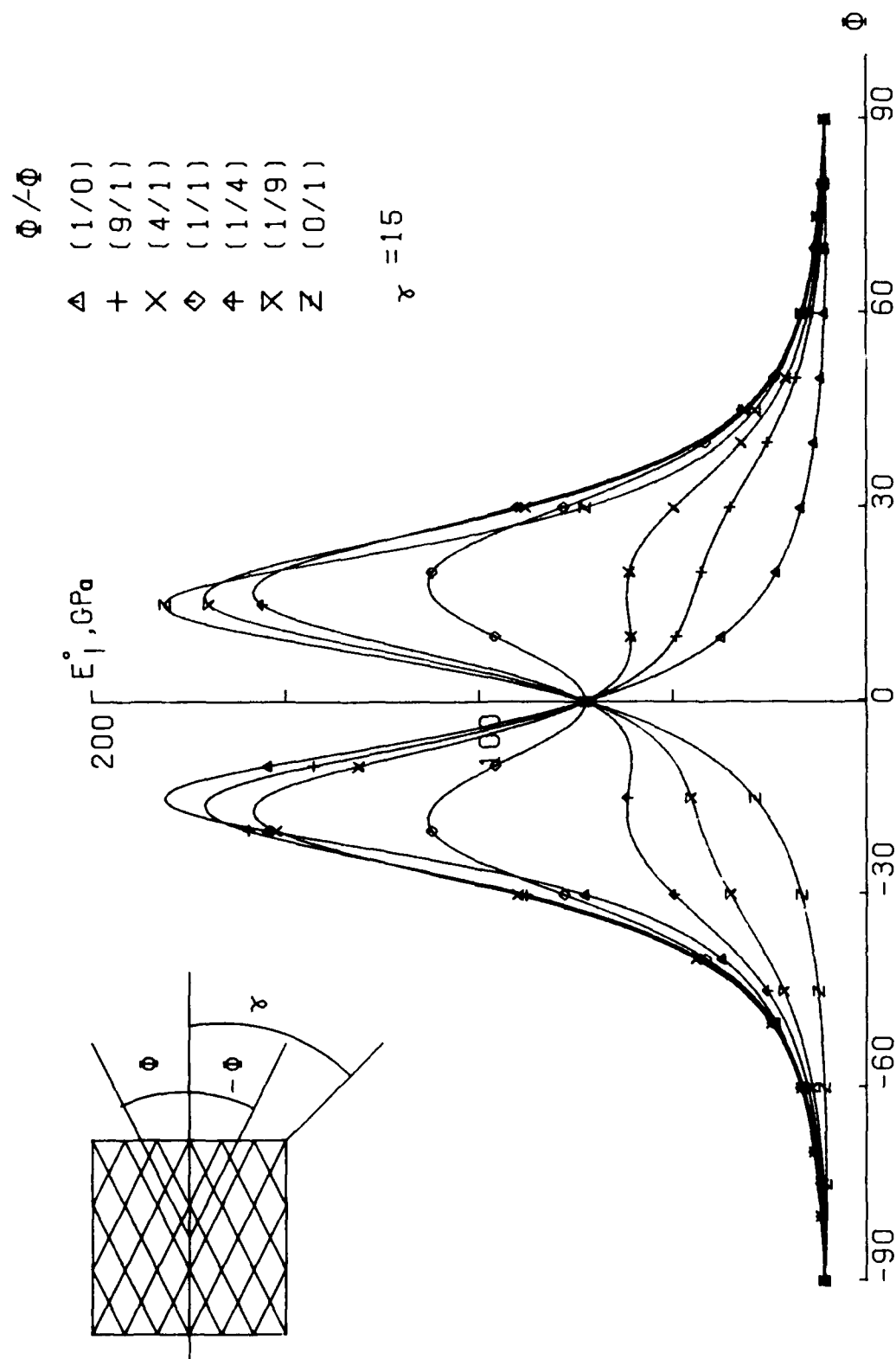


FIG.:295

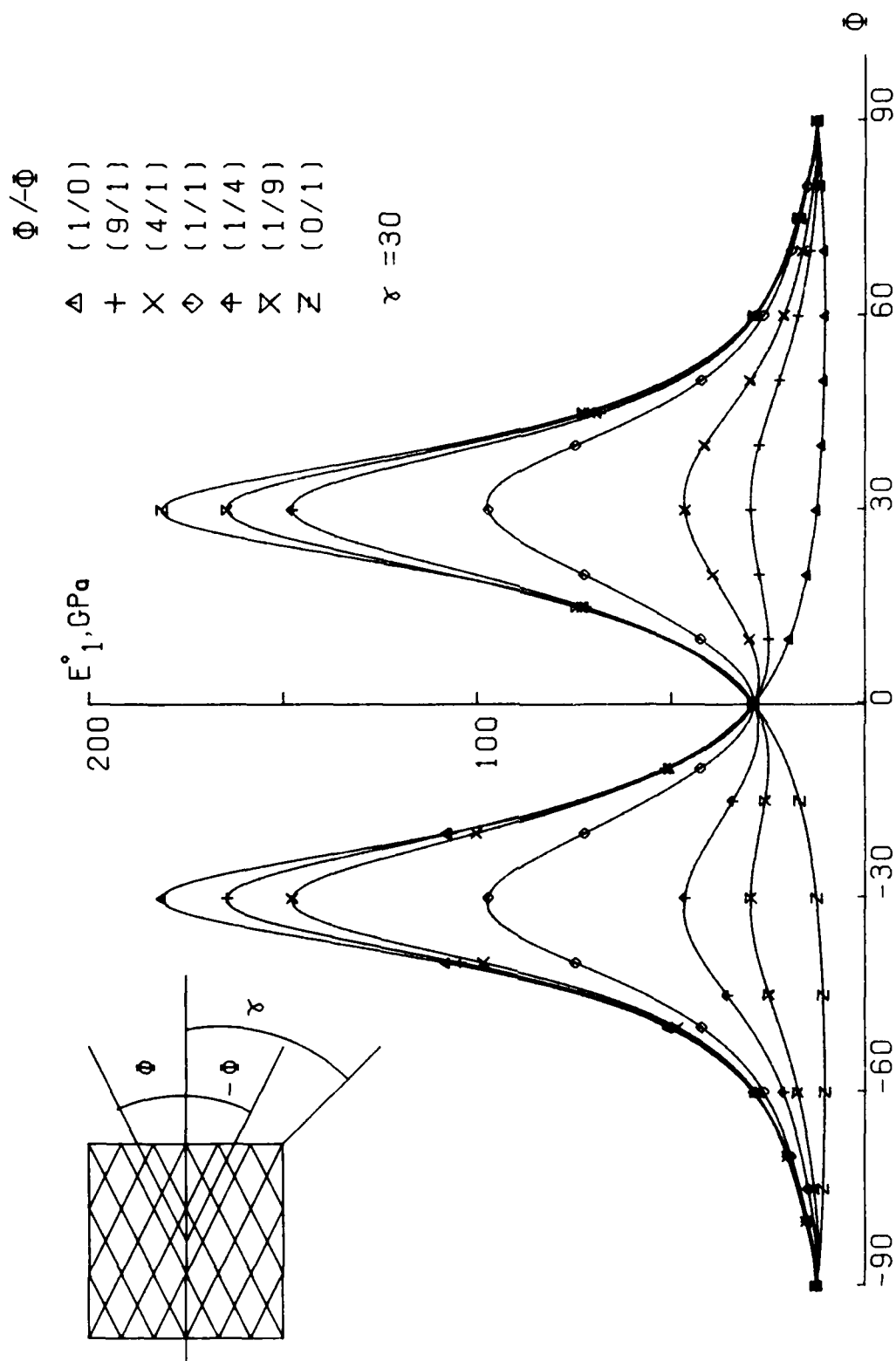


FIG.:296

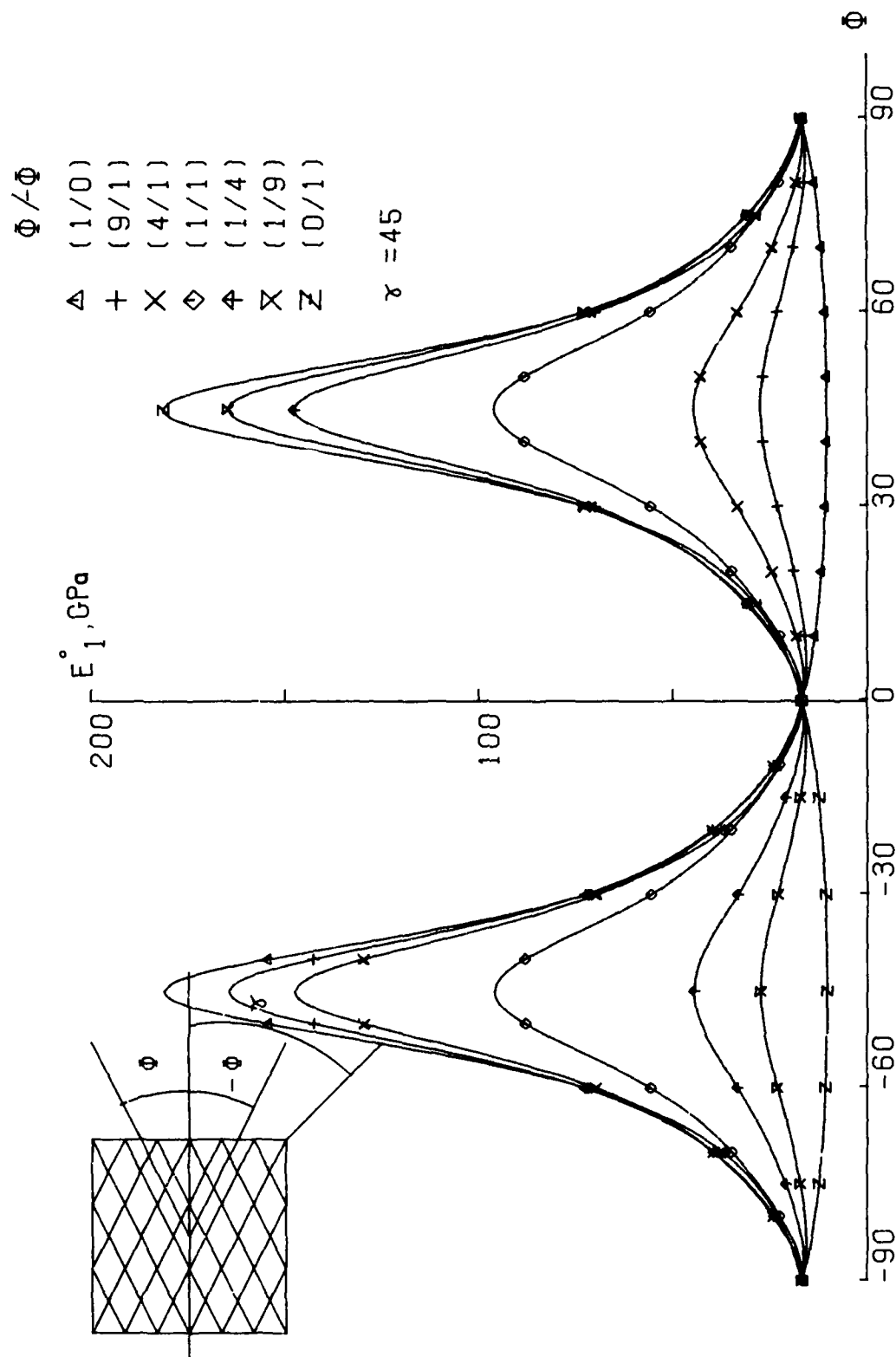


FIG.:297

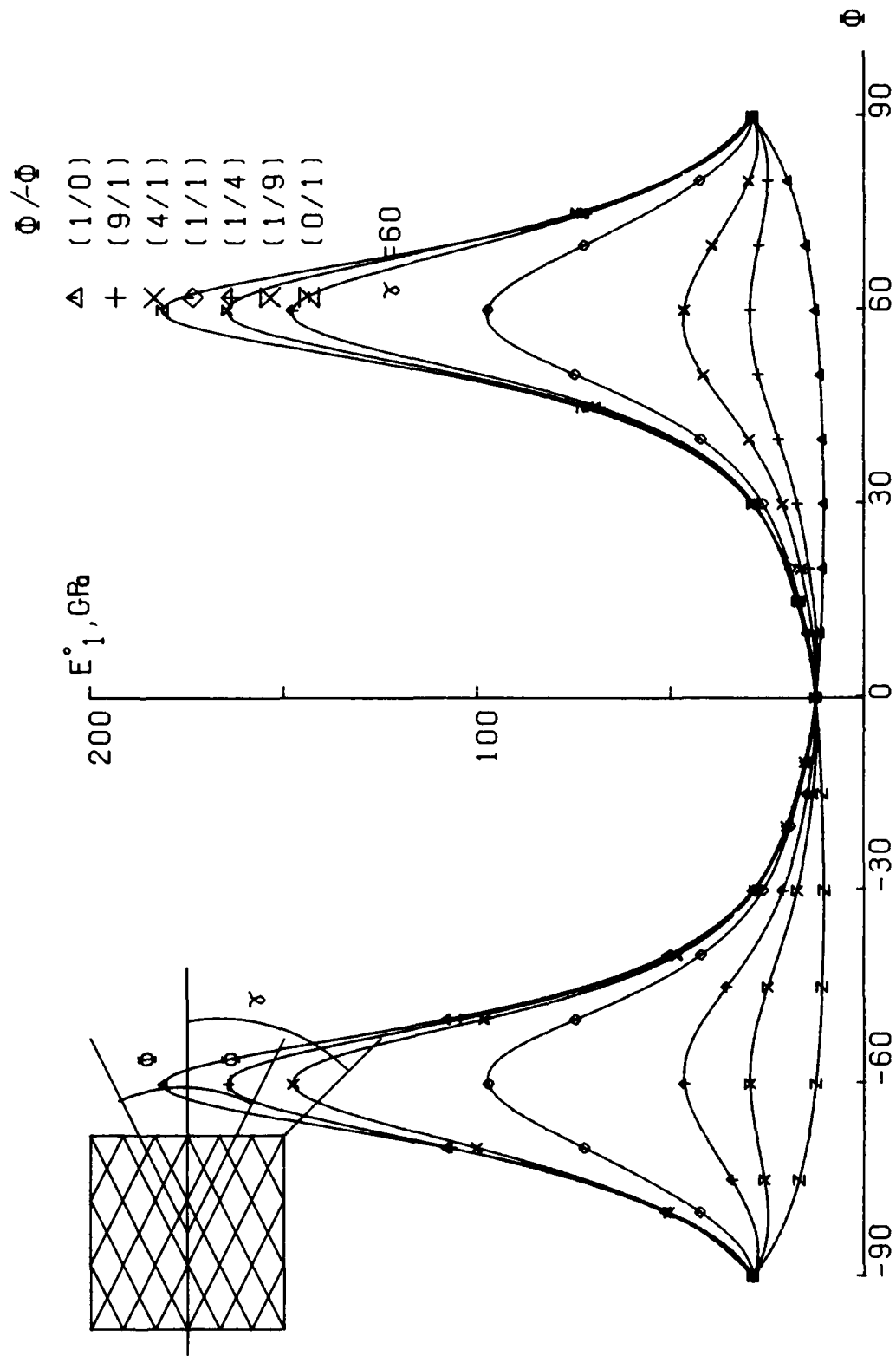


FIG.:298

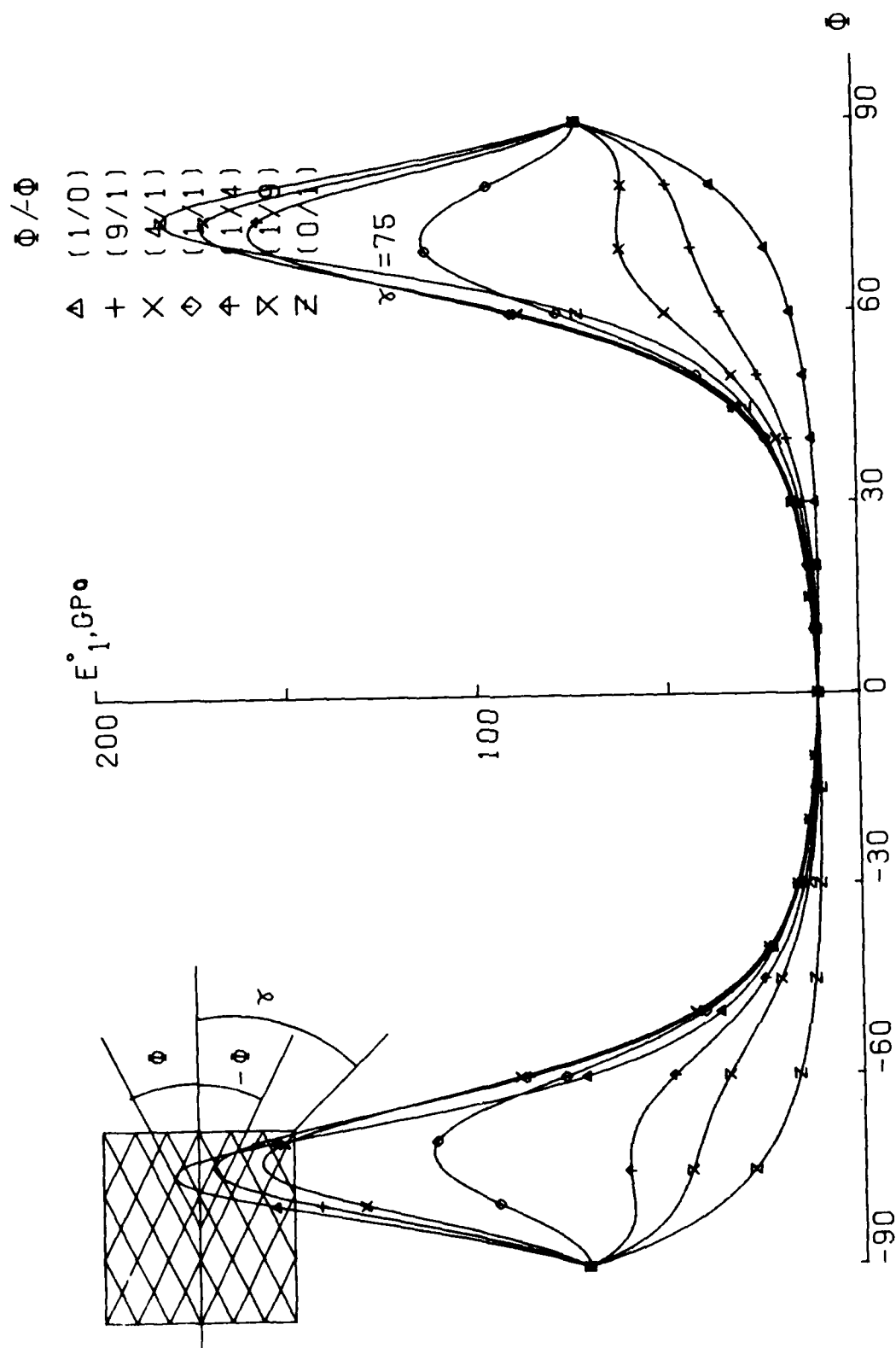


FIG.:299

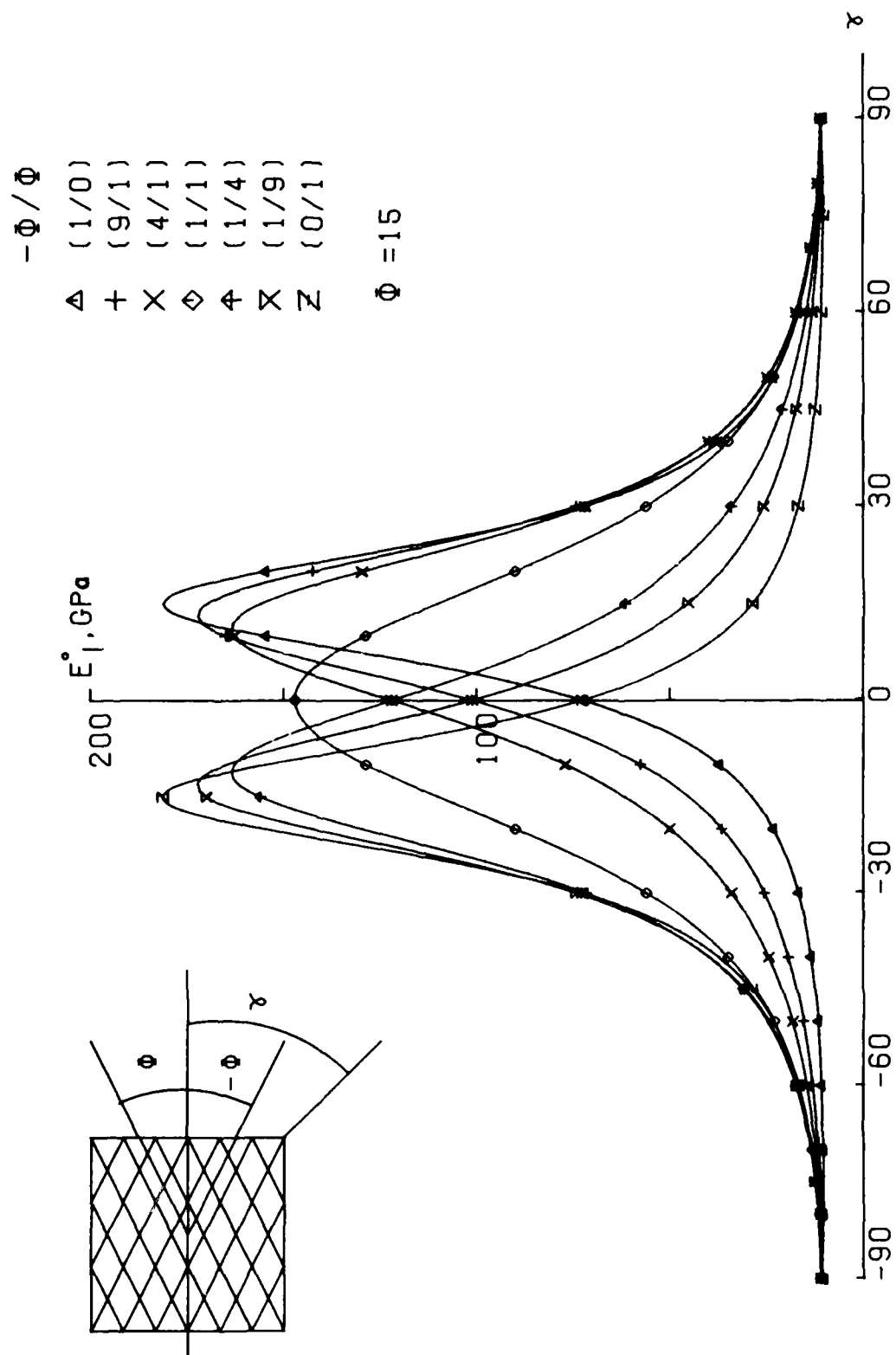


FIG.:300

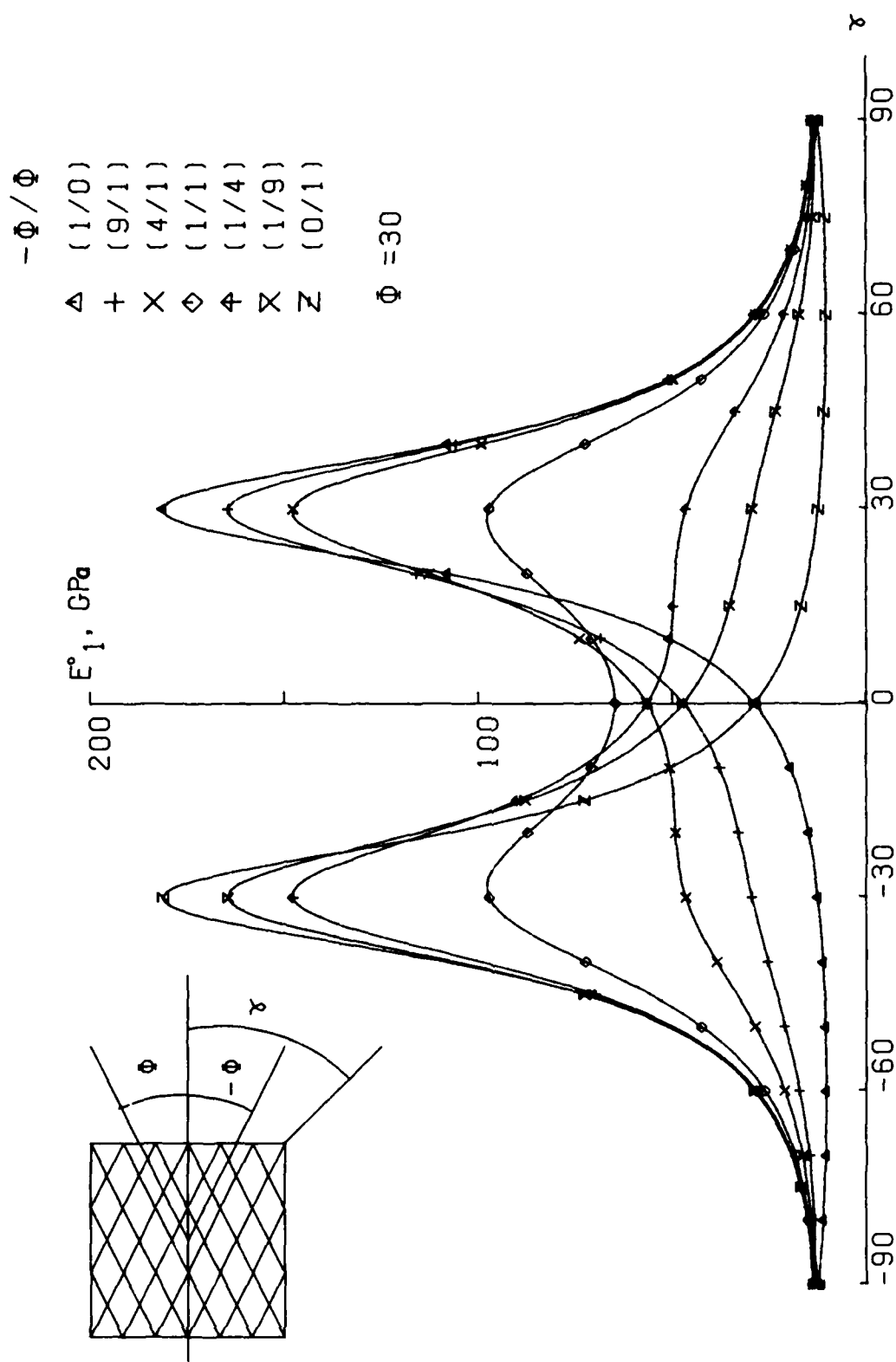


FIG.: 301

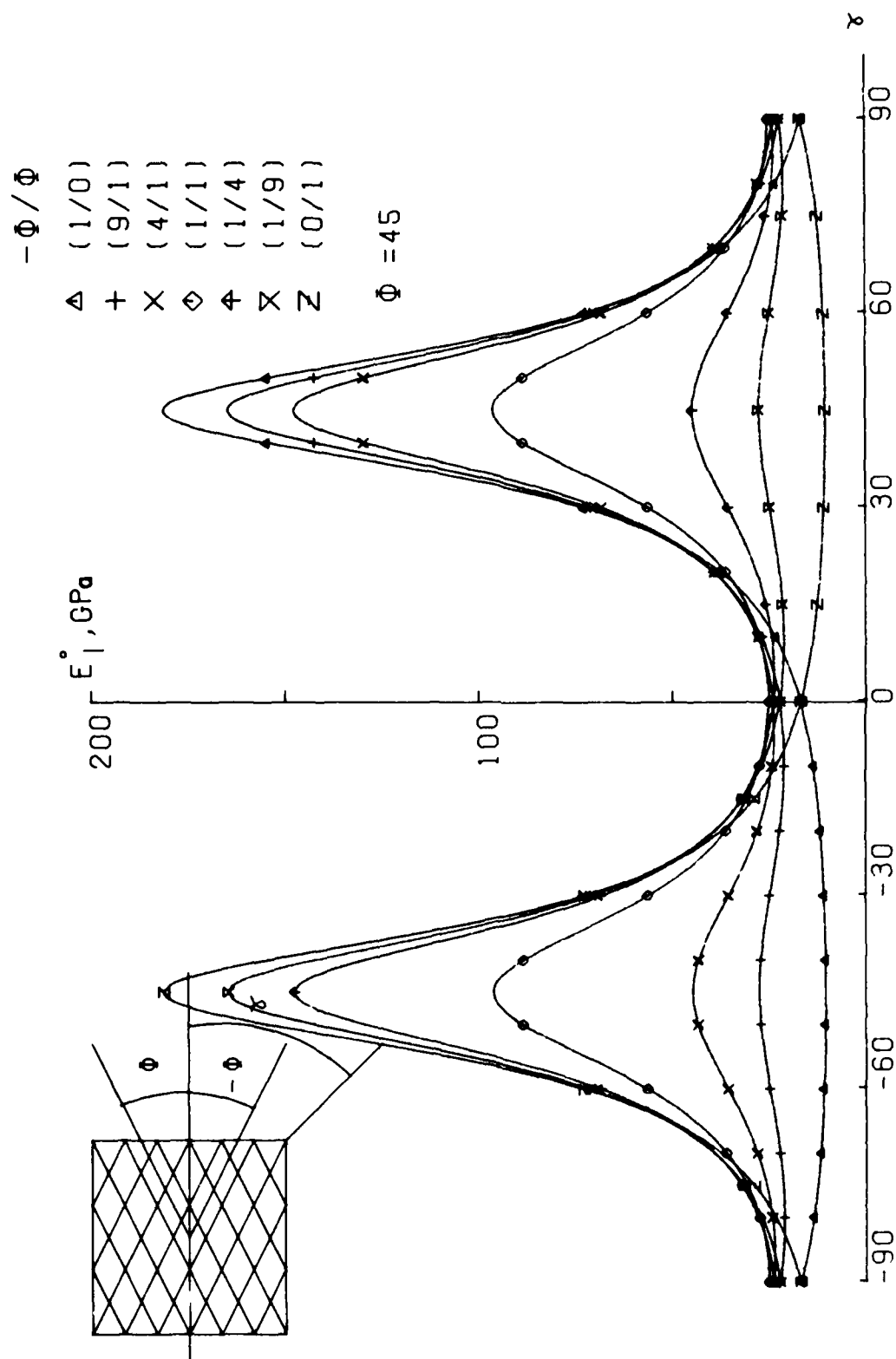


FIG.: 302

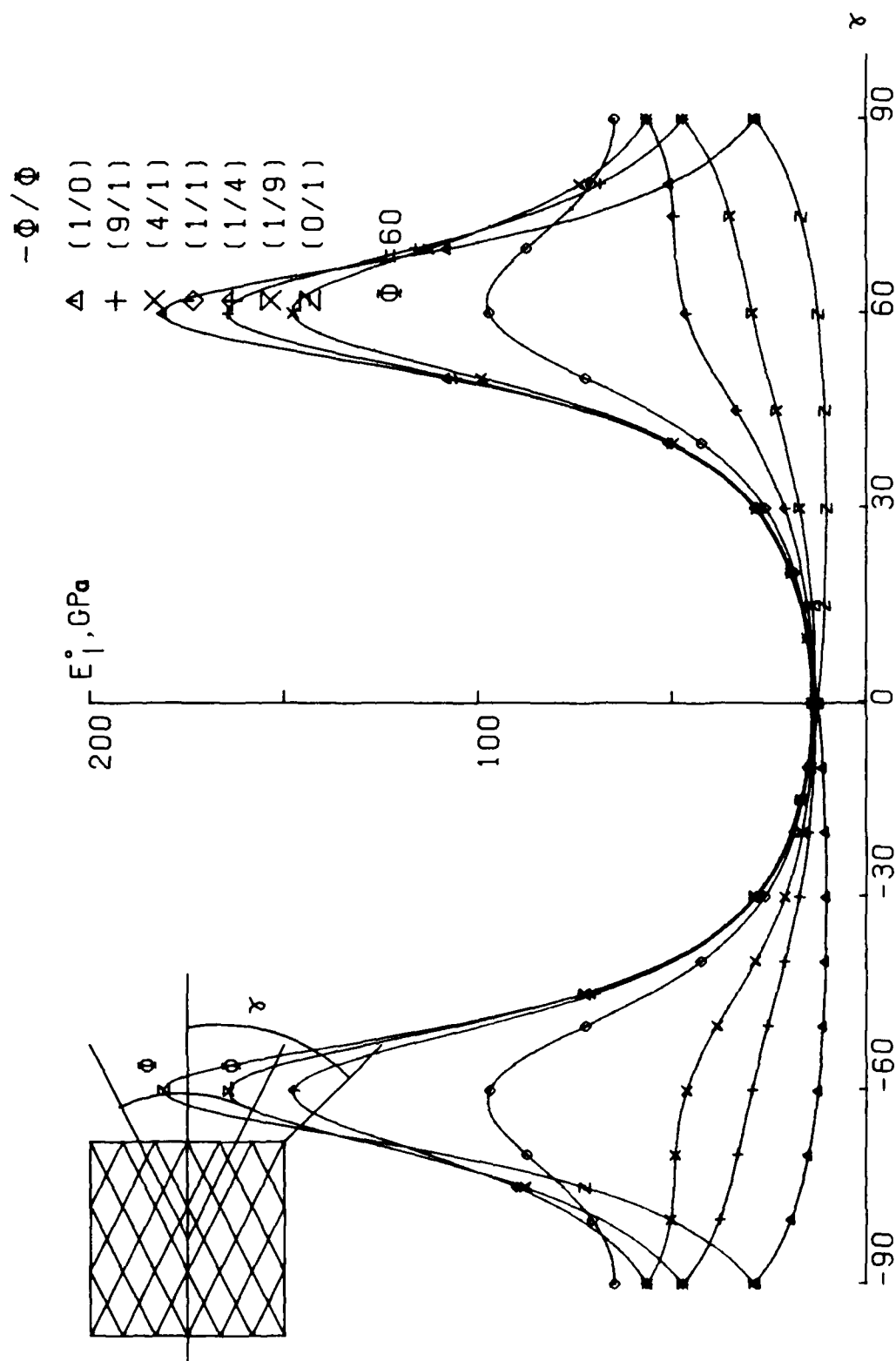


FIG.: 303

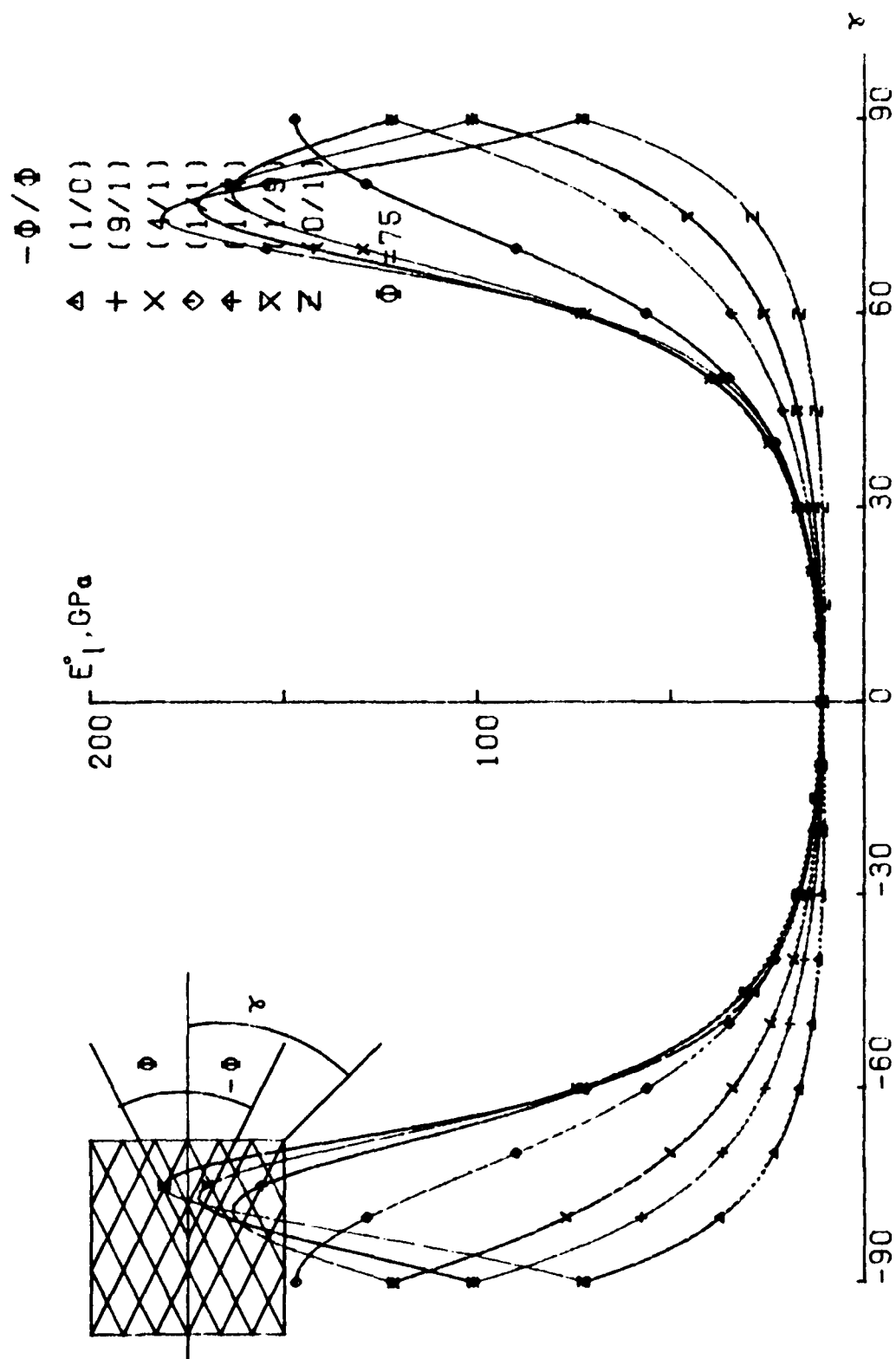


FIG.: 304

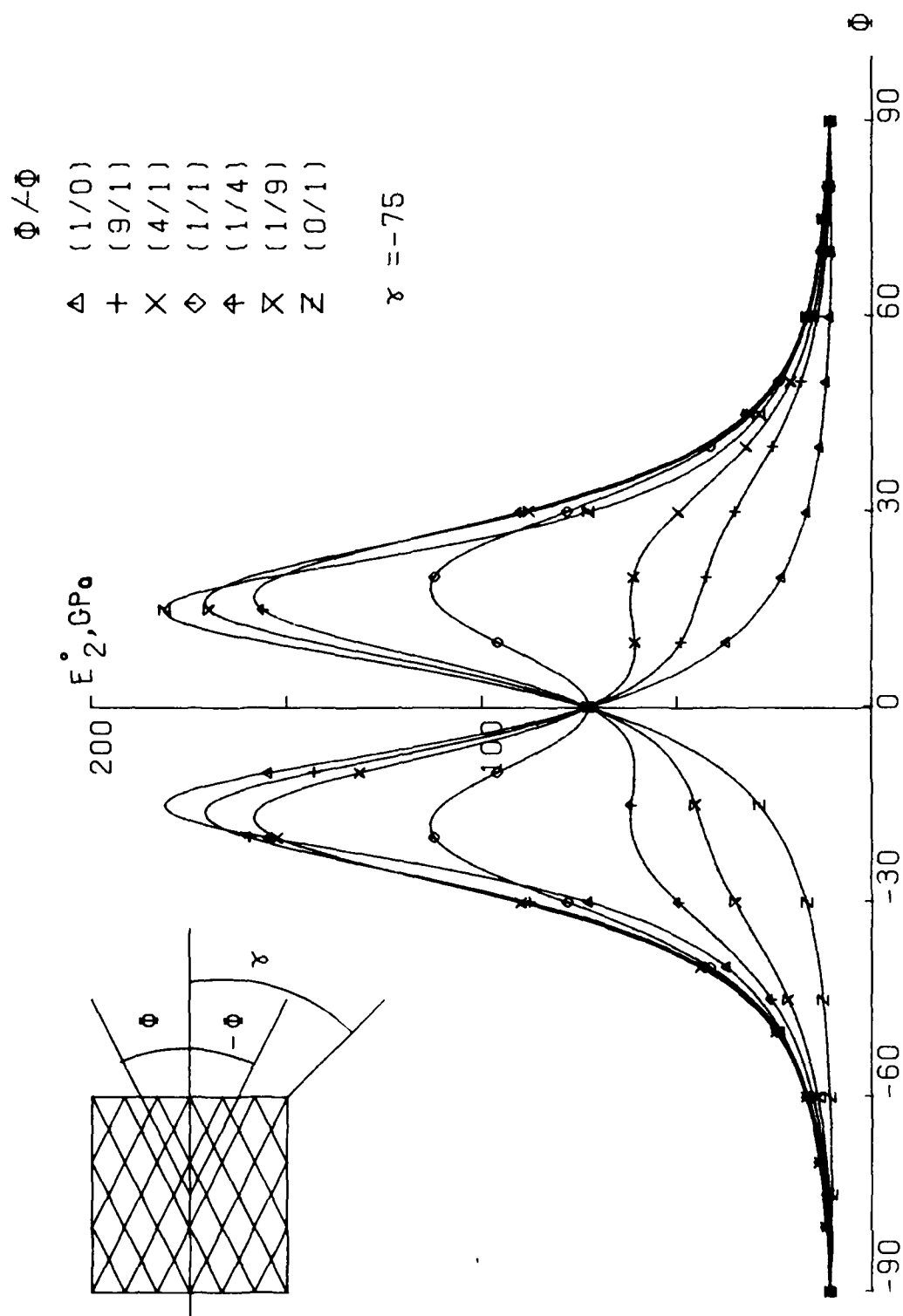


FIG.: 305

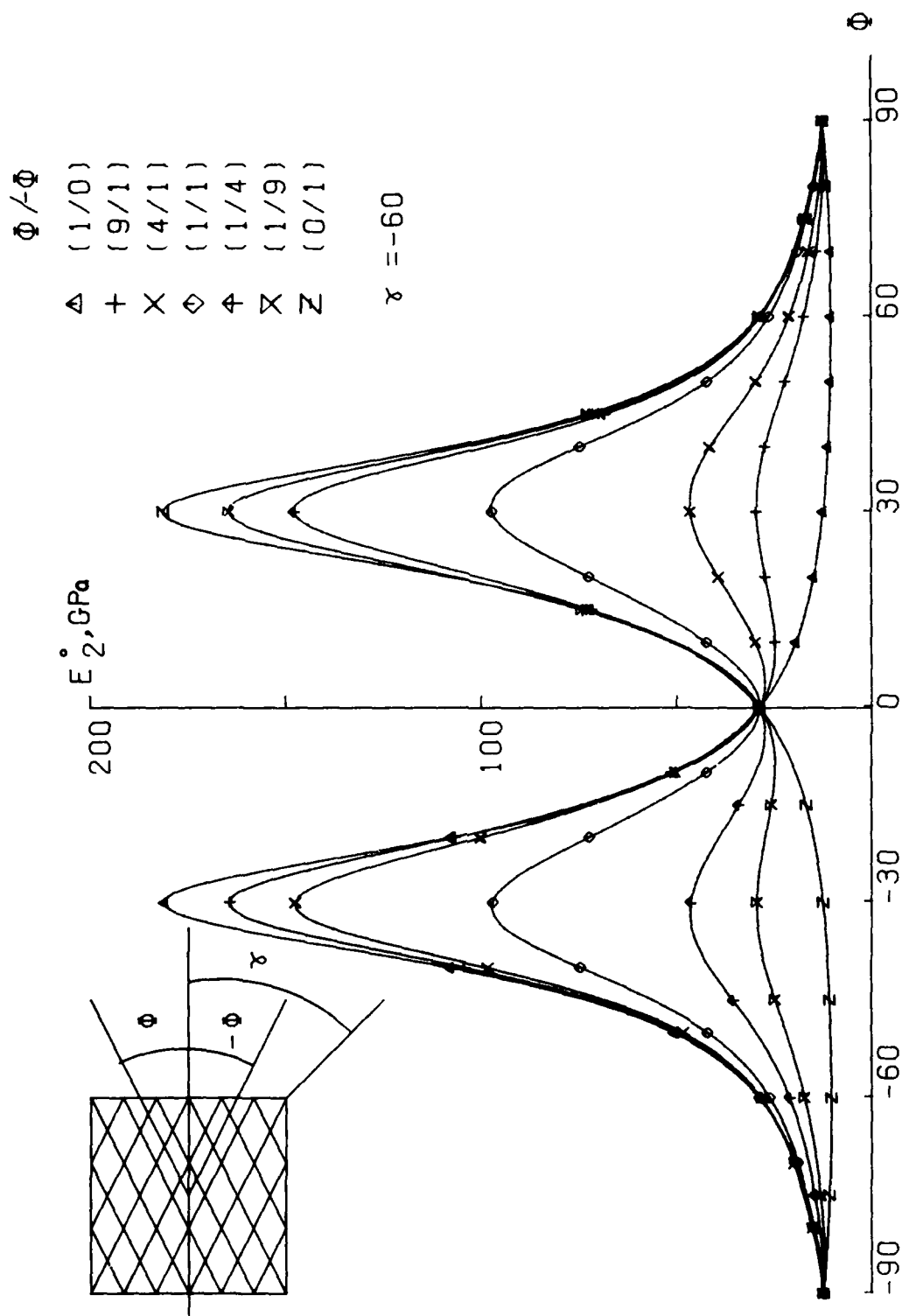


FIG.: 306

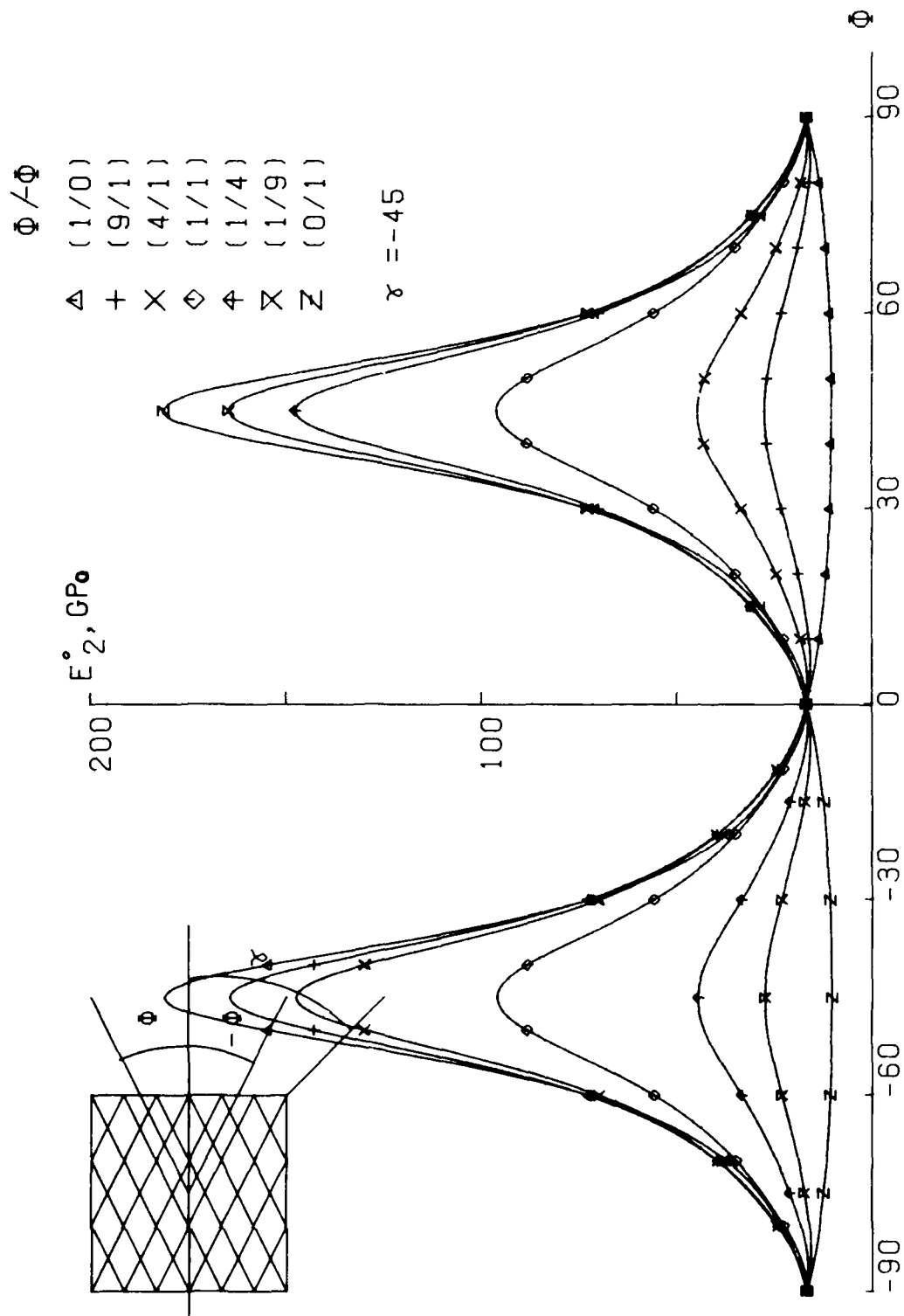


FIG.:307

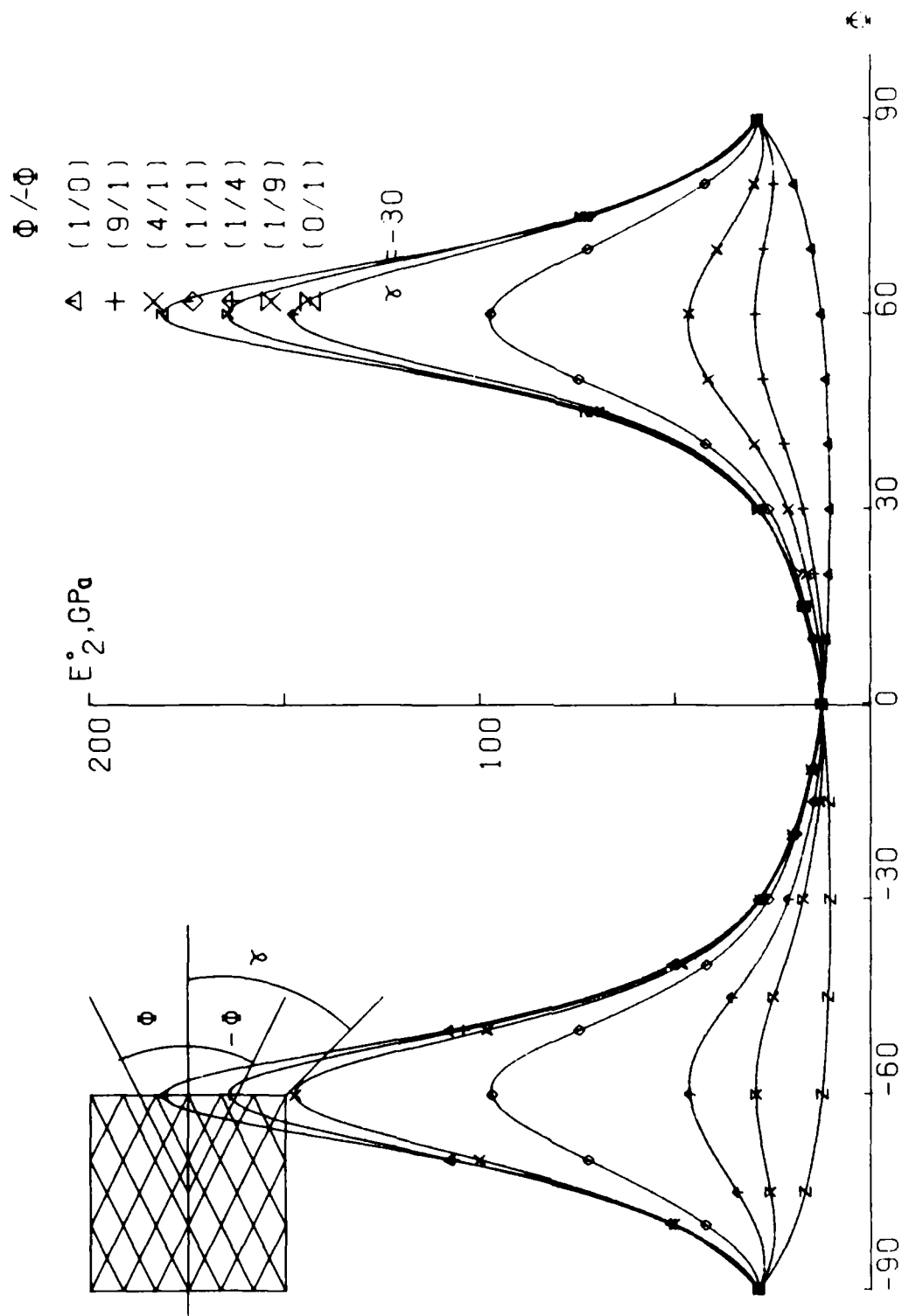


FIG.: 308

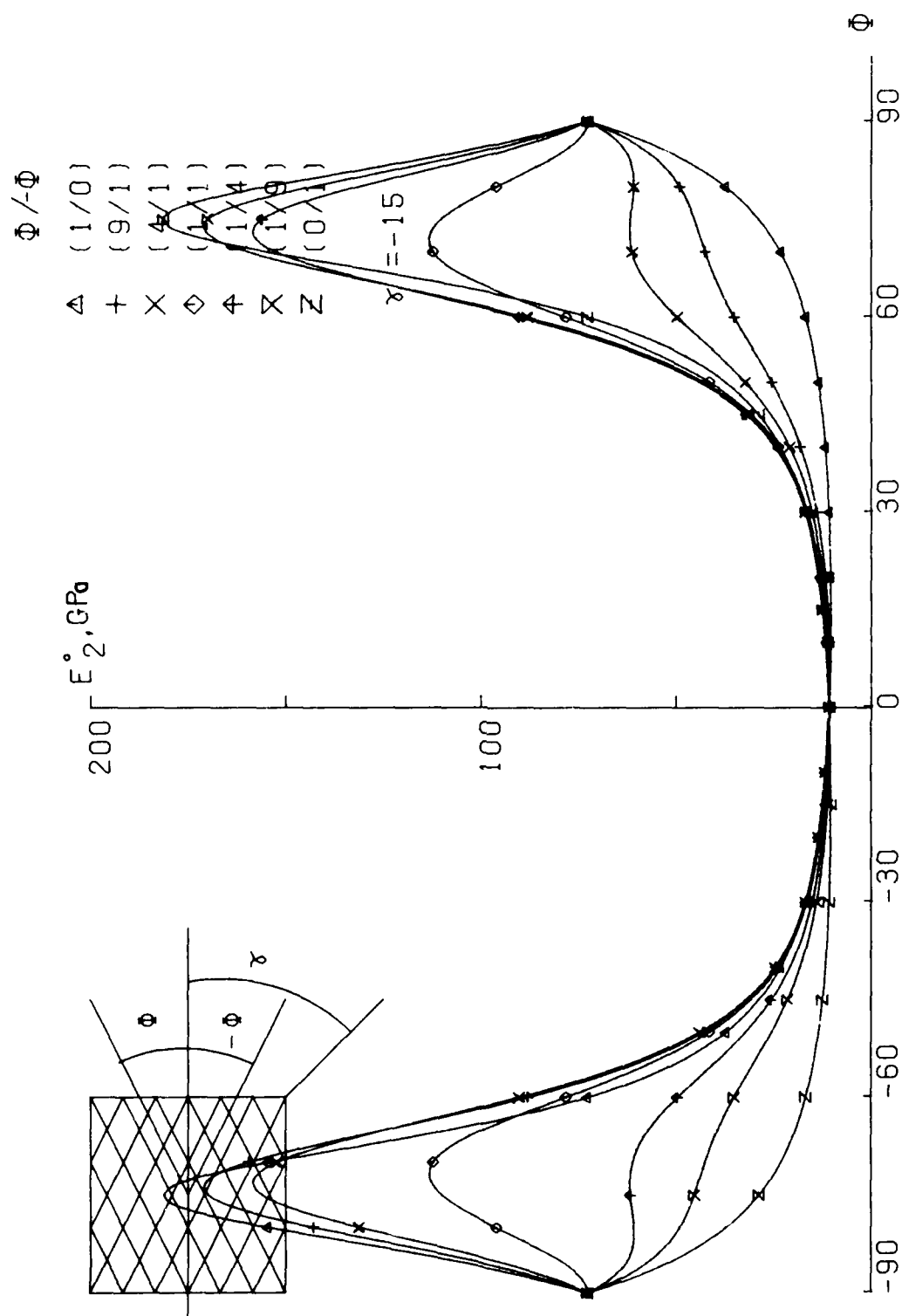


FIG.:309

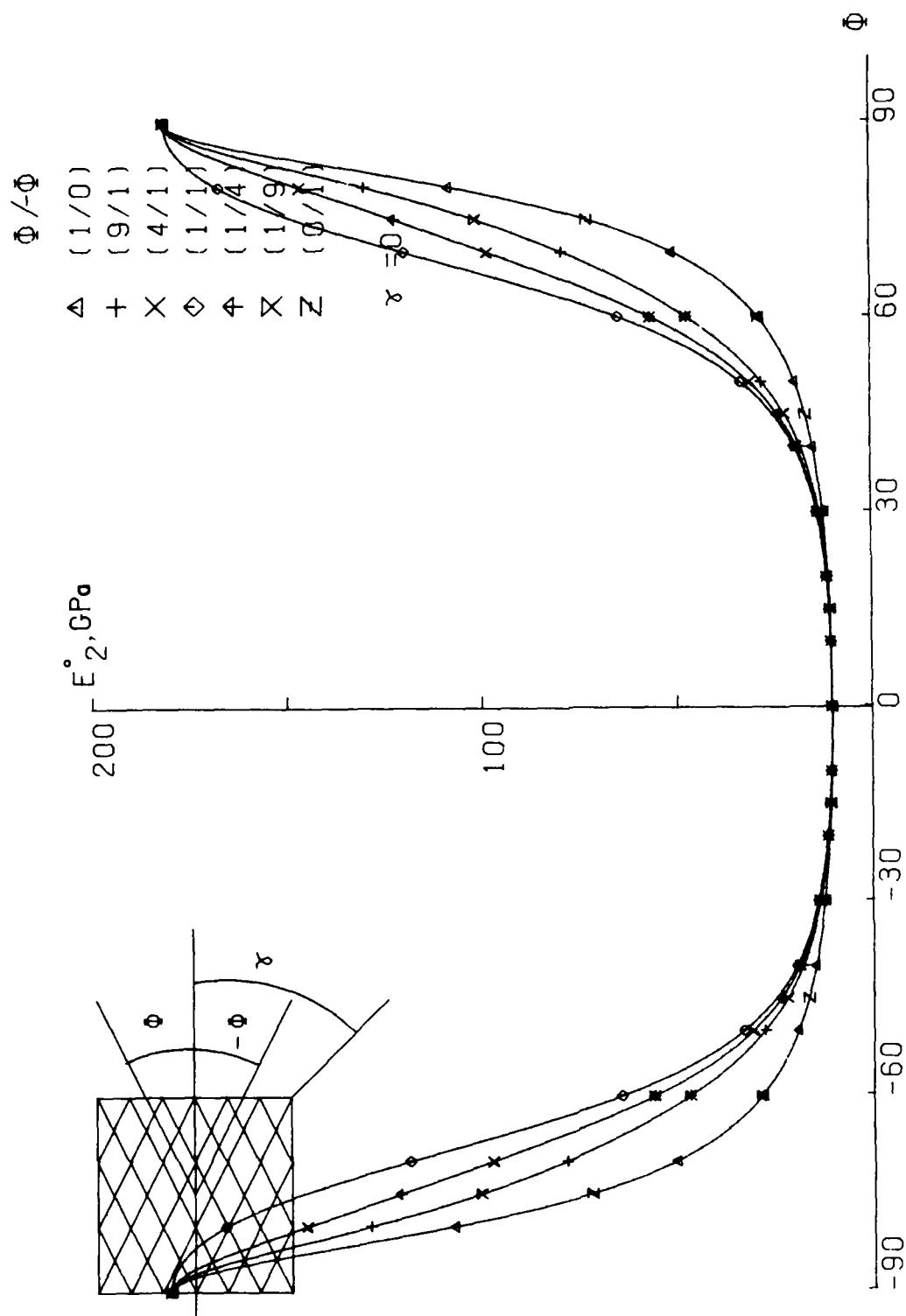


FIG.:310

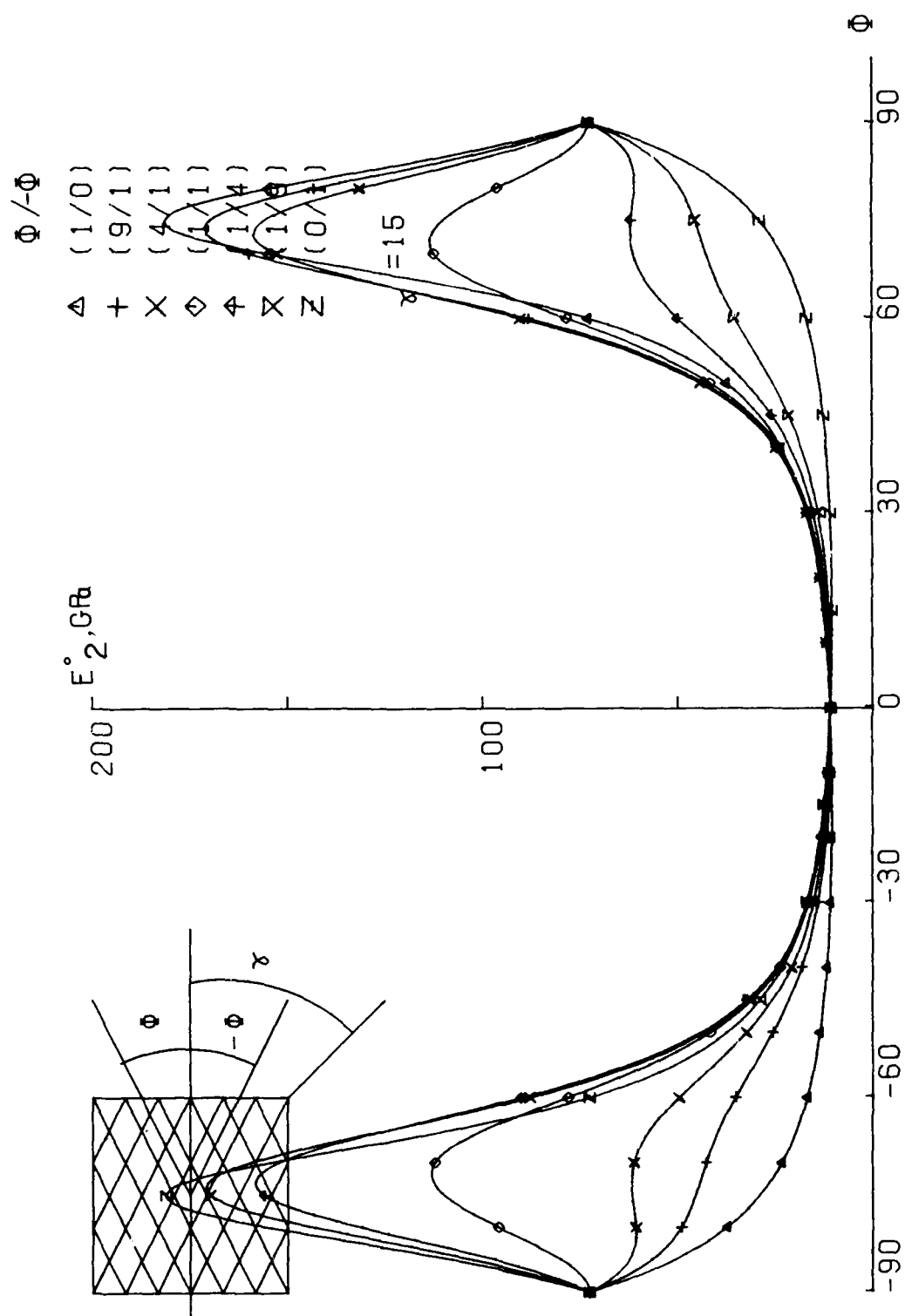


FIG.:311

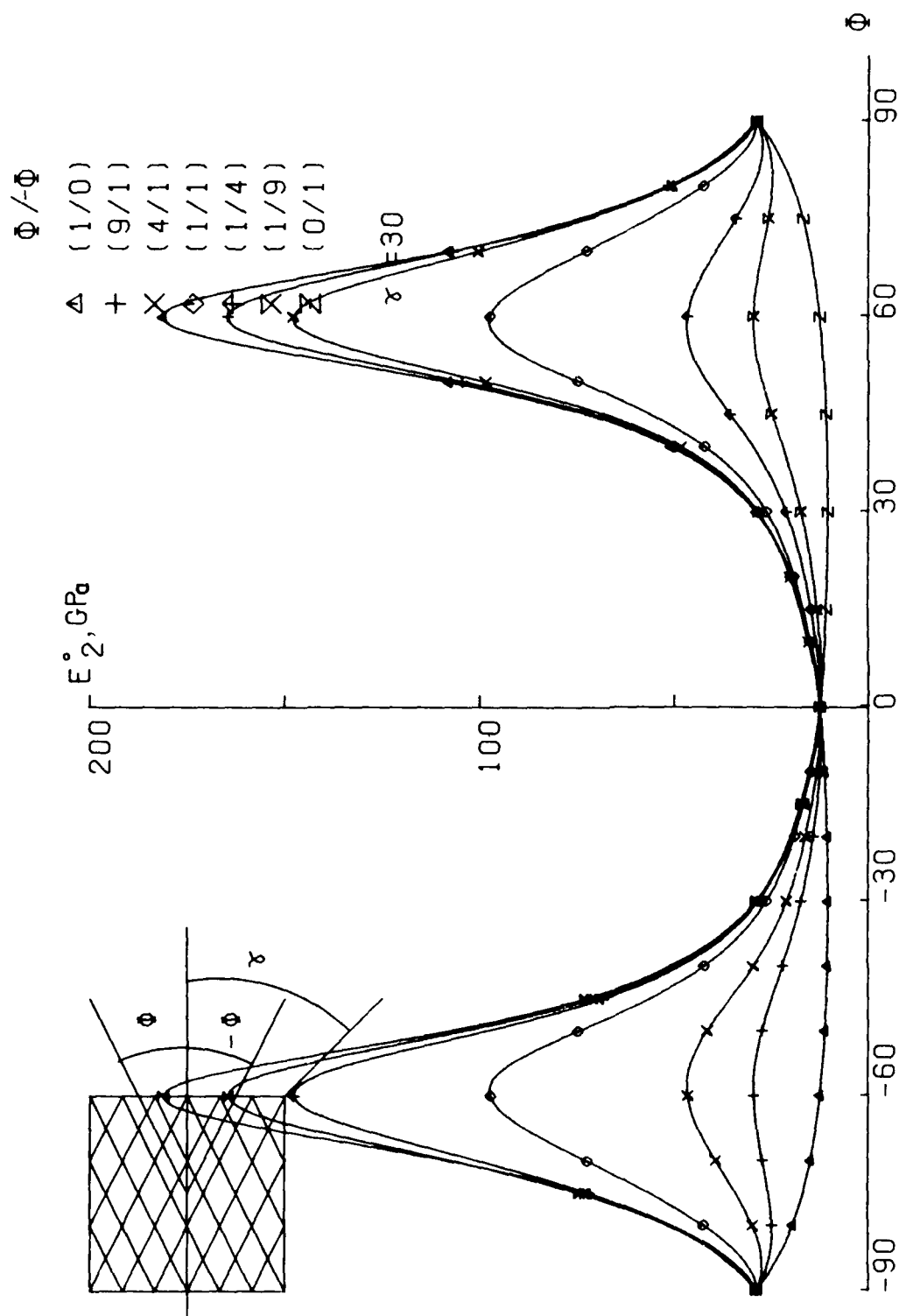


FIG.:312

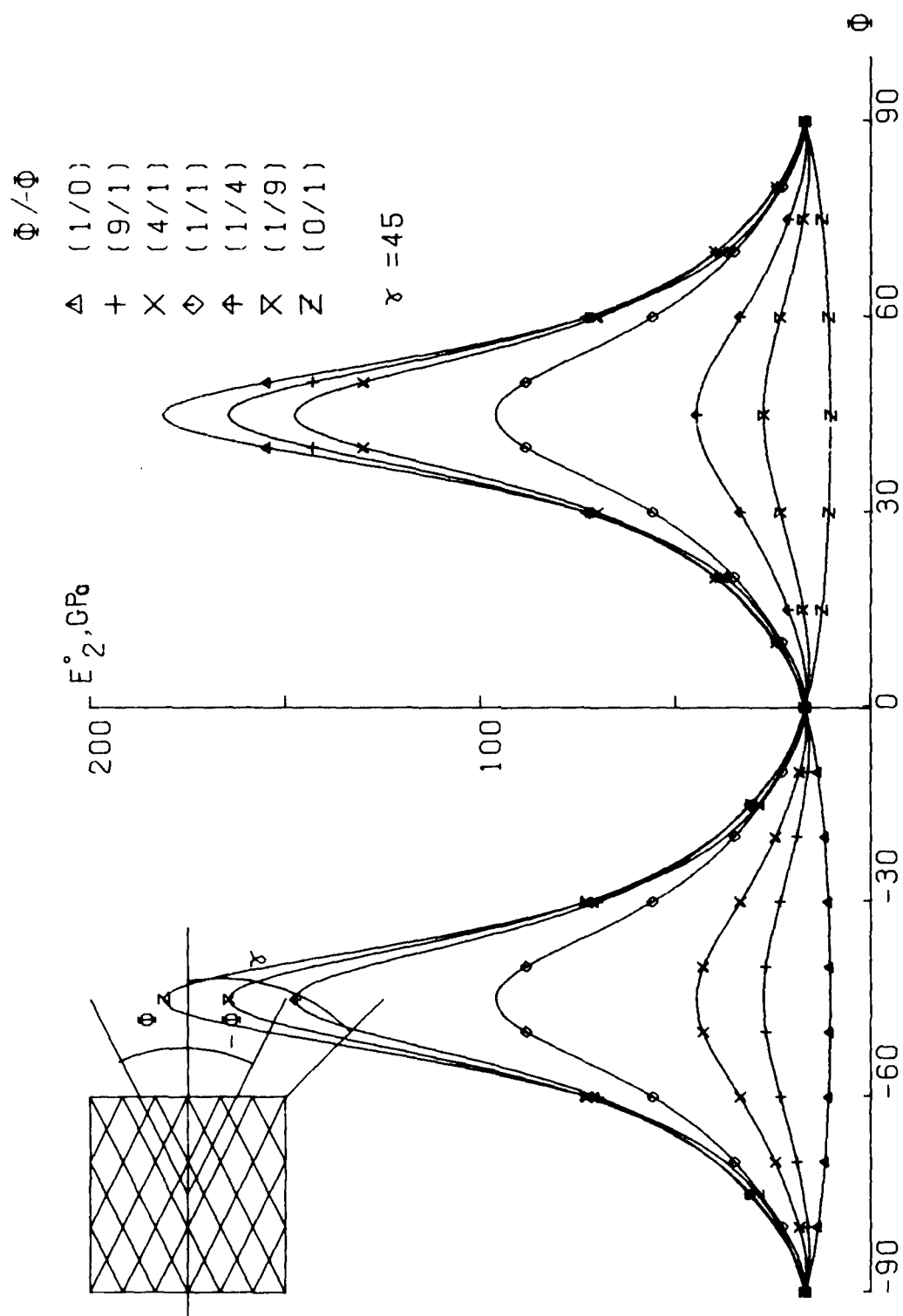


FIG.: 313

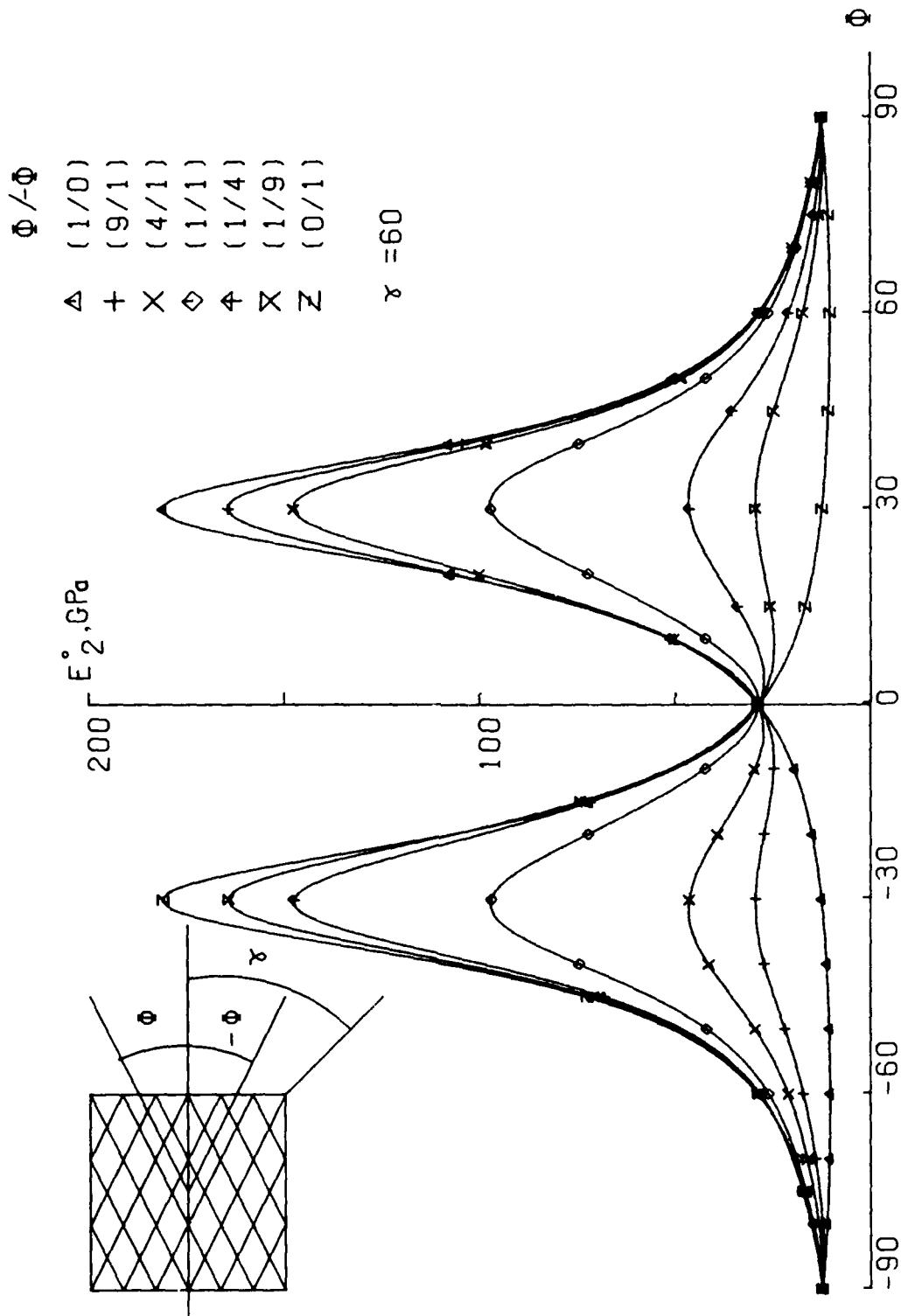


FIG.: 314

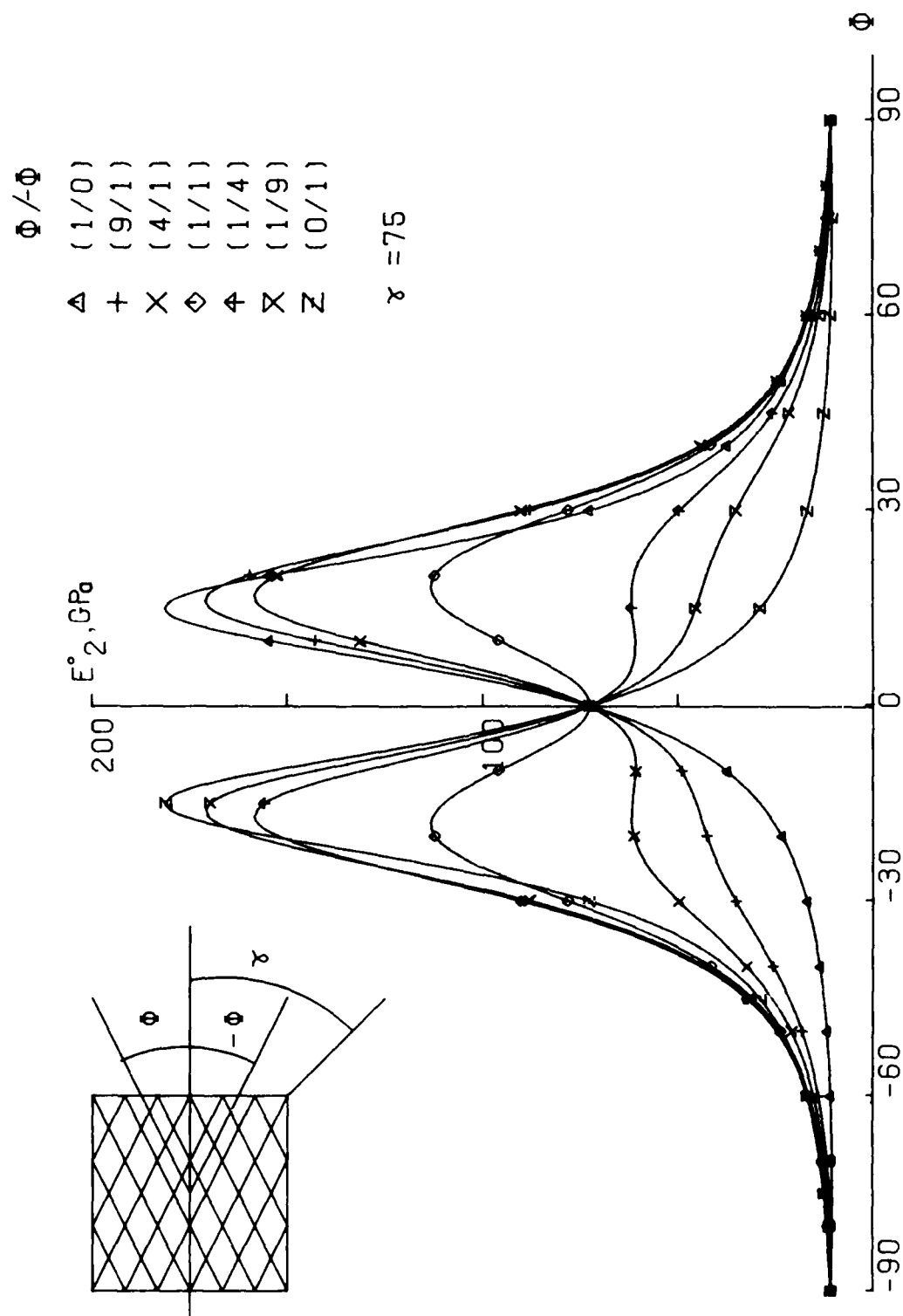


FIG.: 315

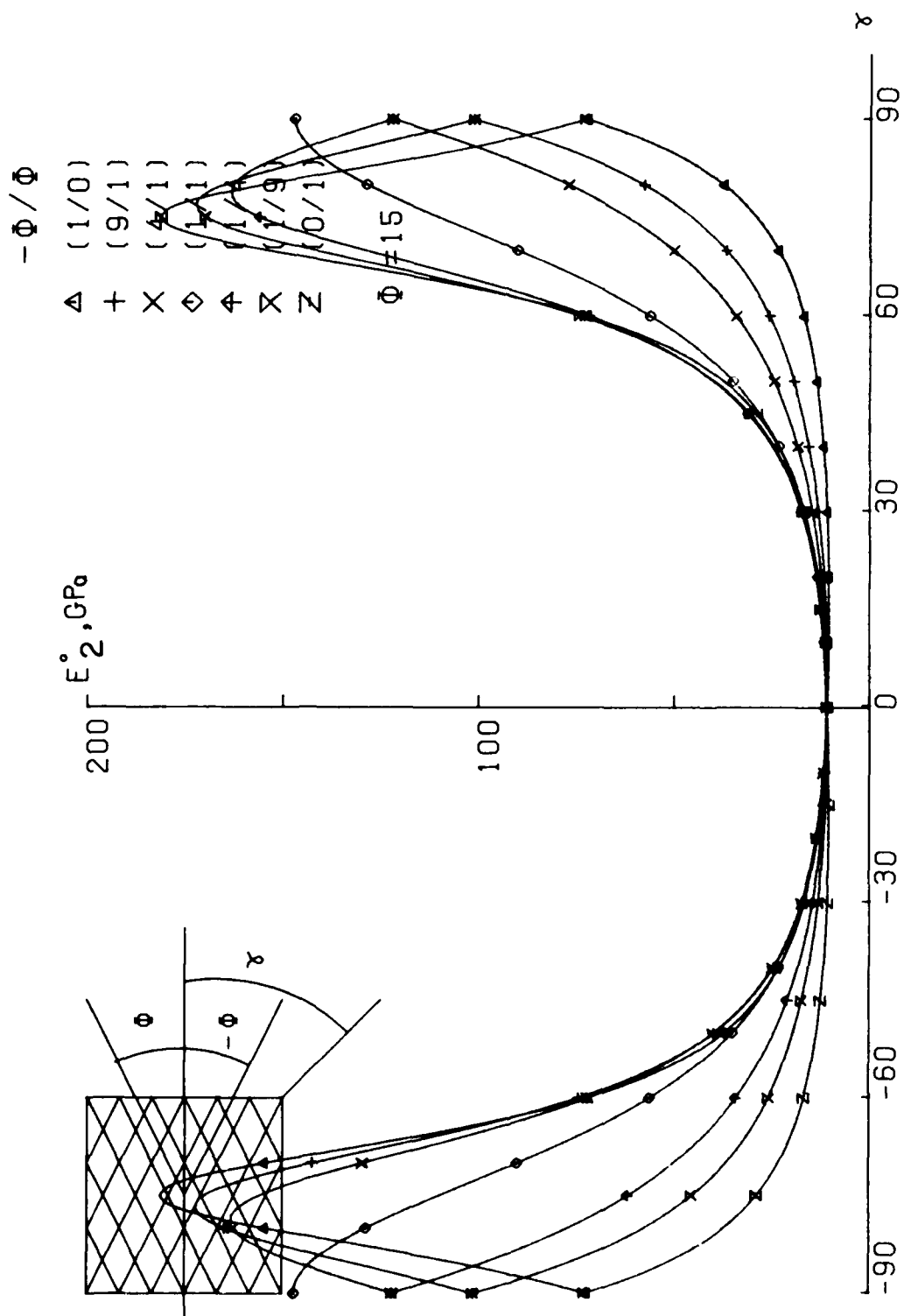


FIG.:316

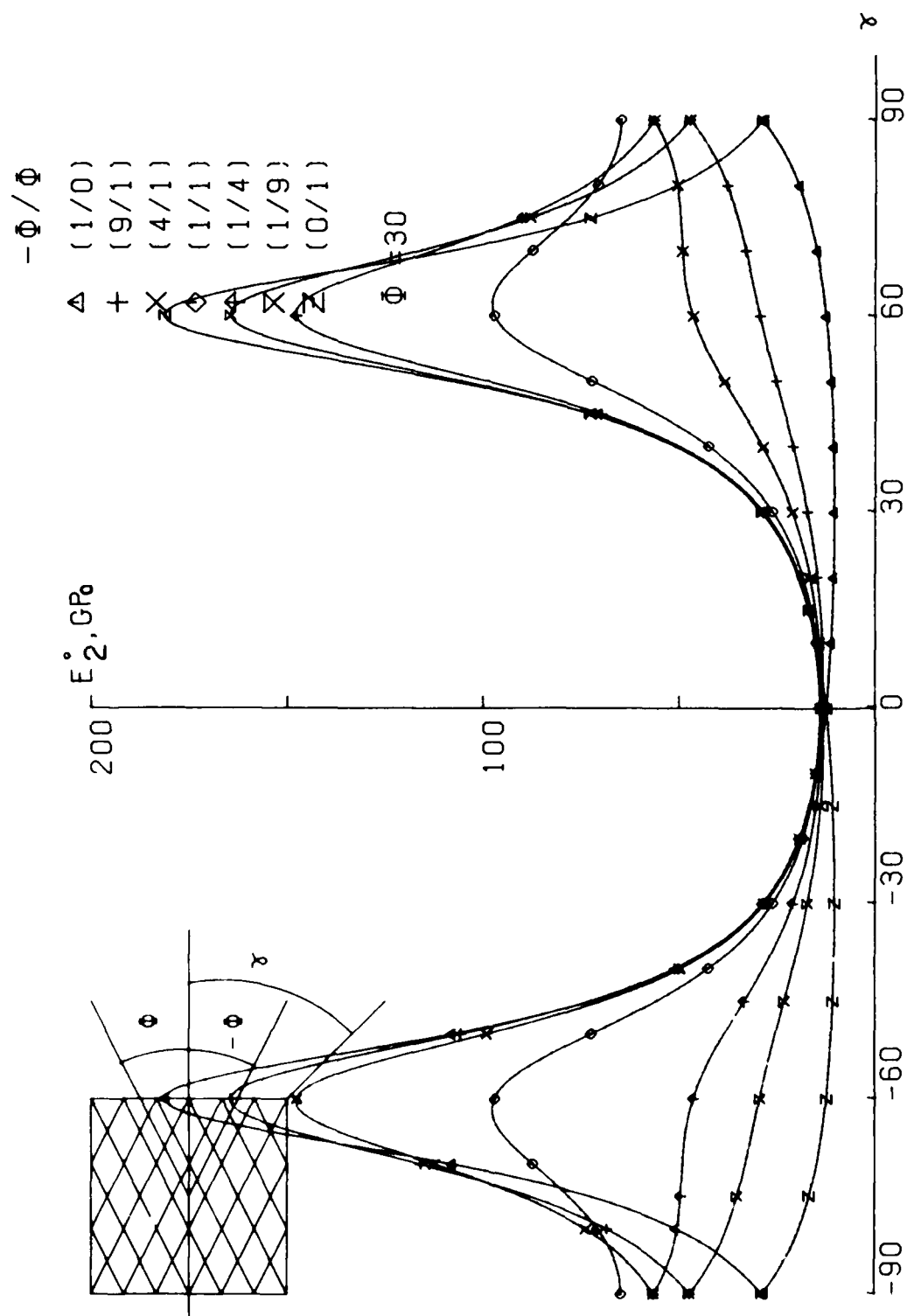


FIG.:317

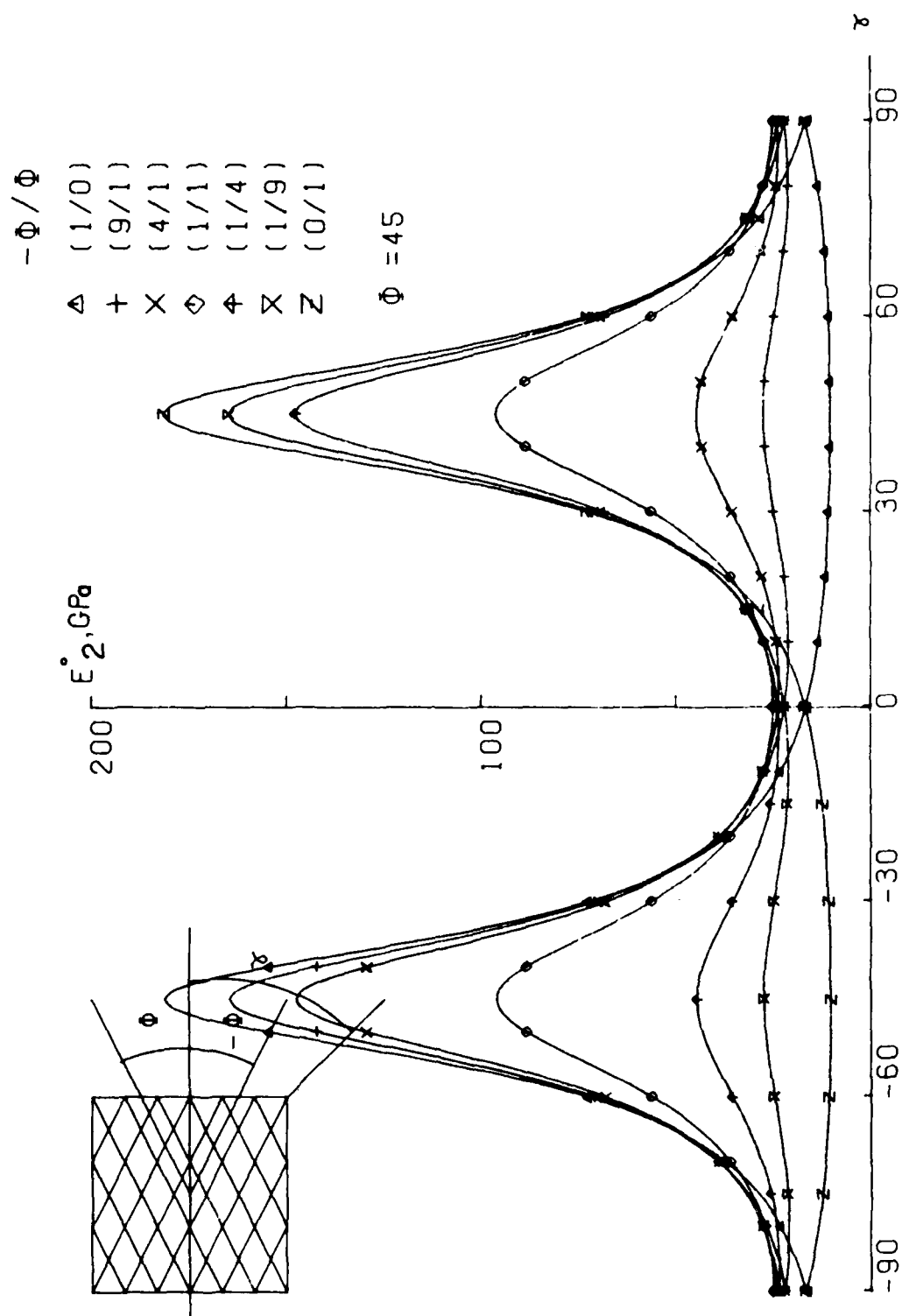


FIG.: 318

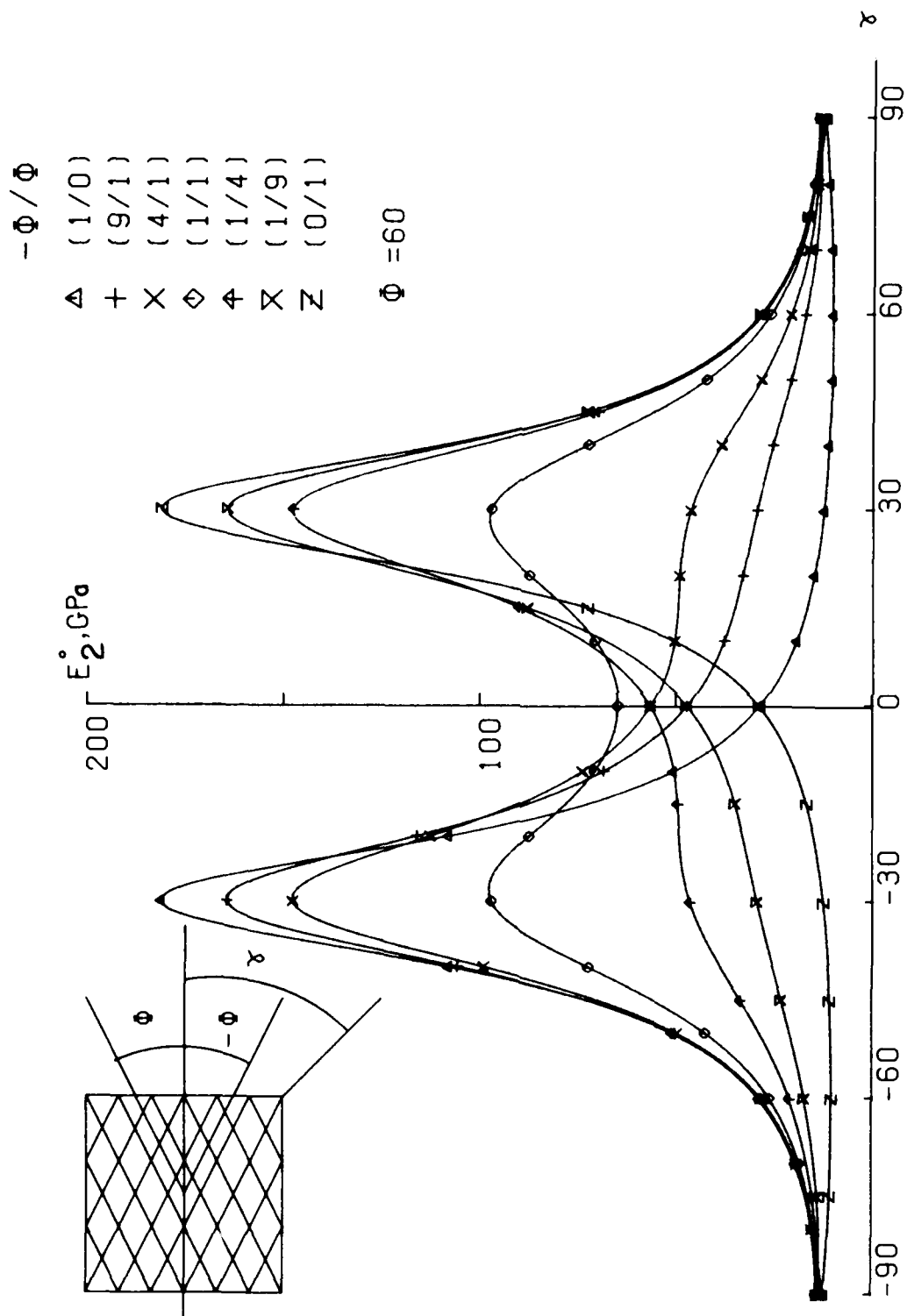


FIG.:319

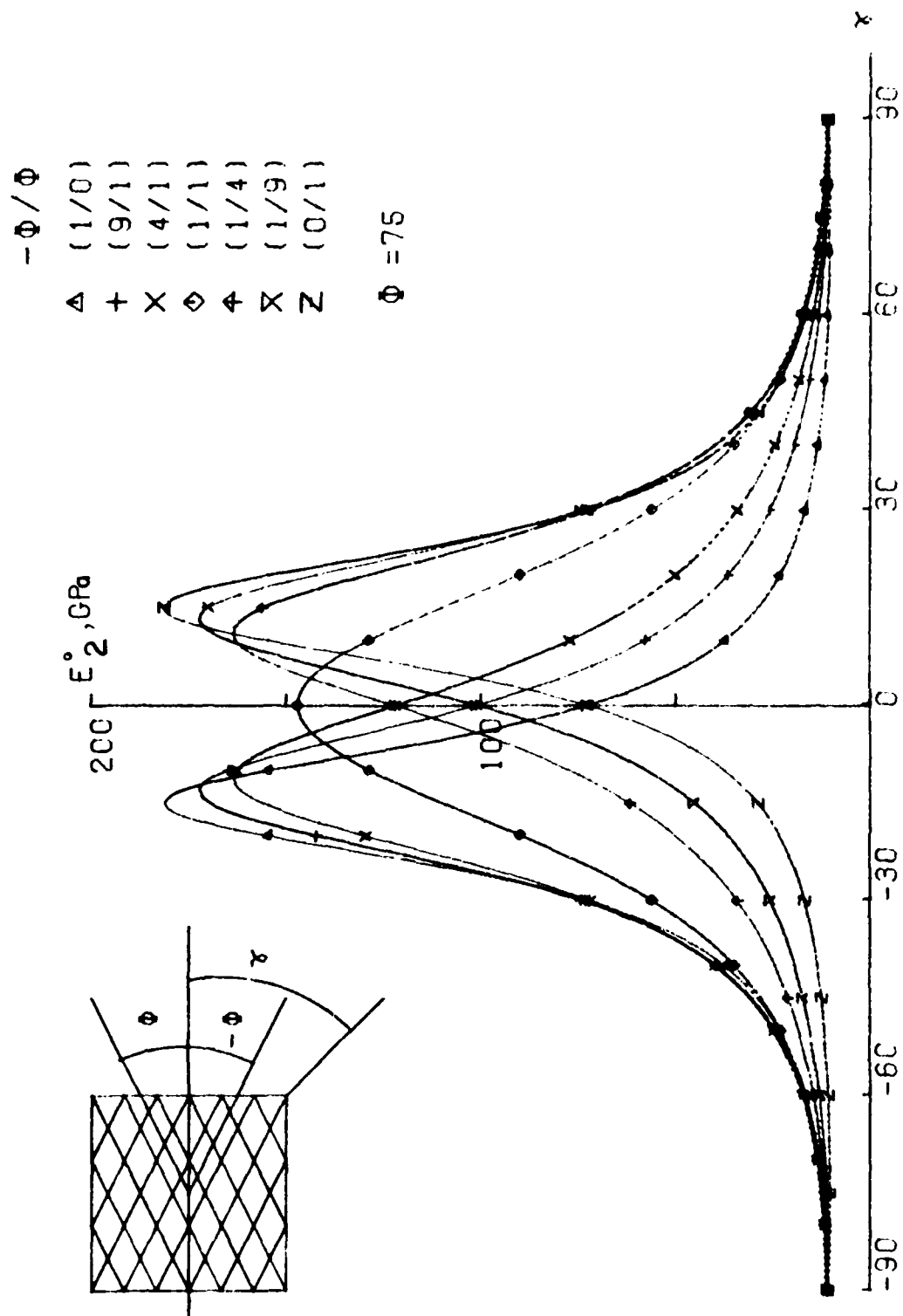


FIG.: 320

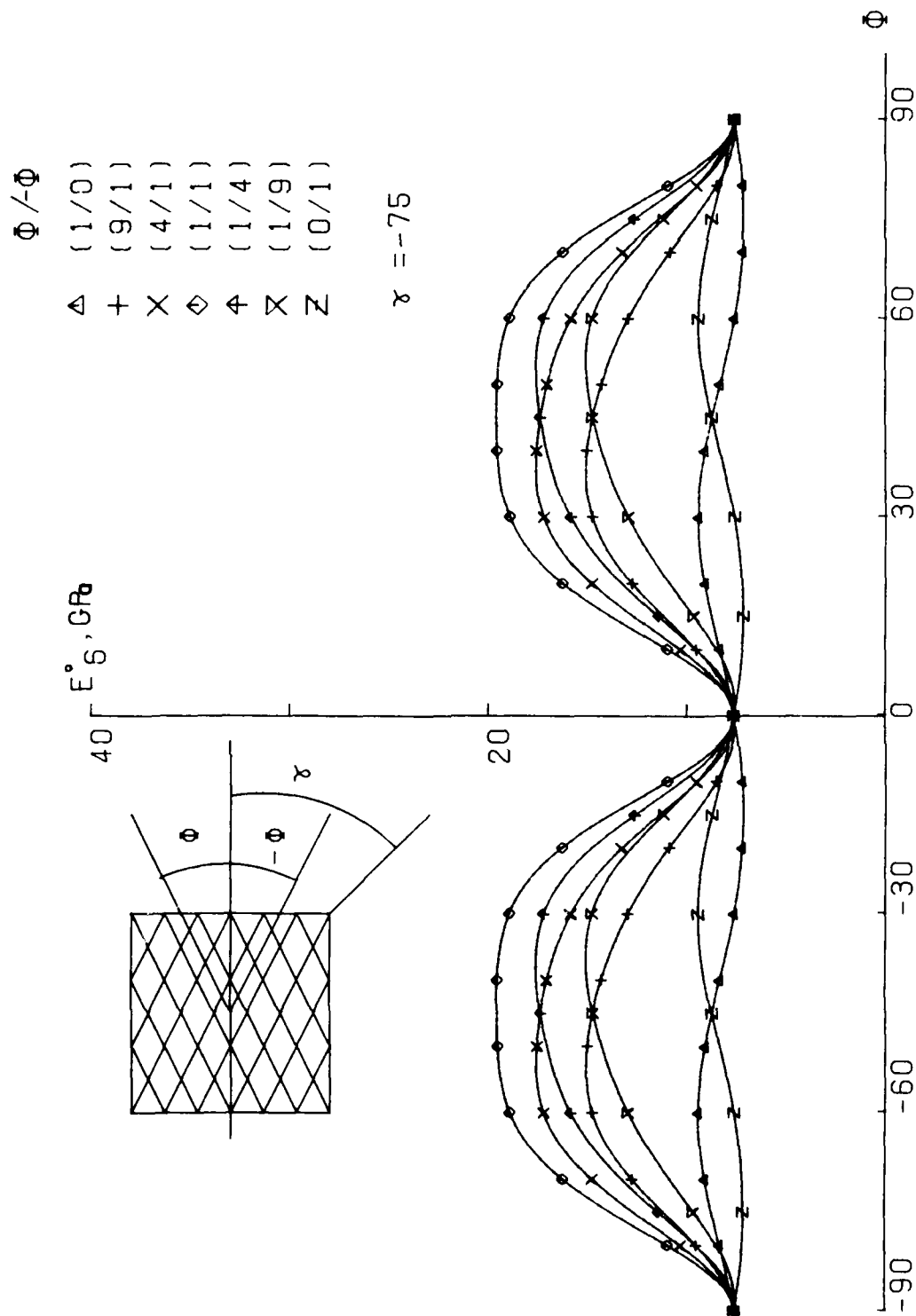


FIG.: 321

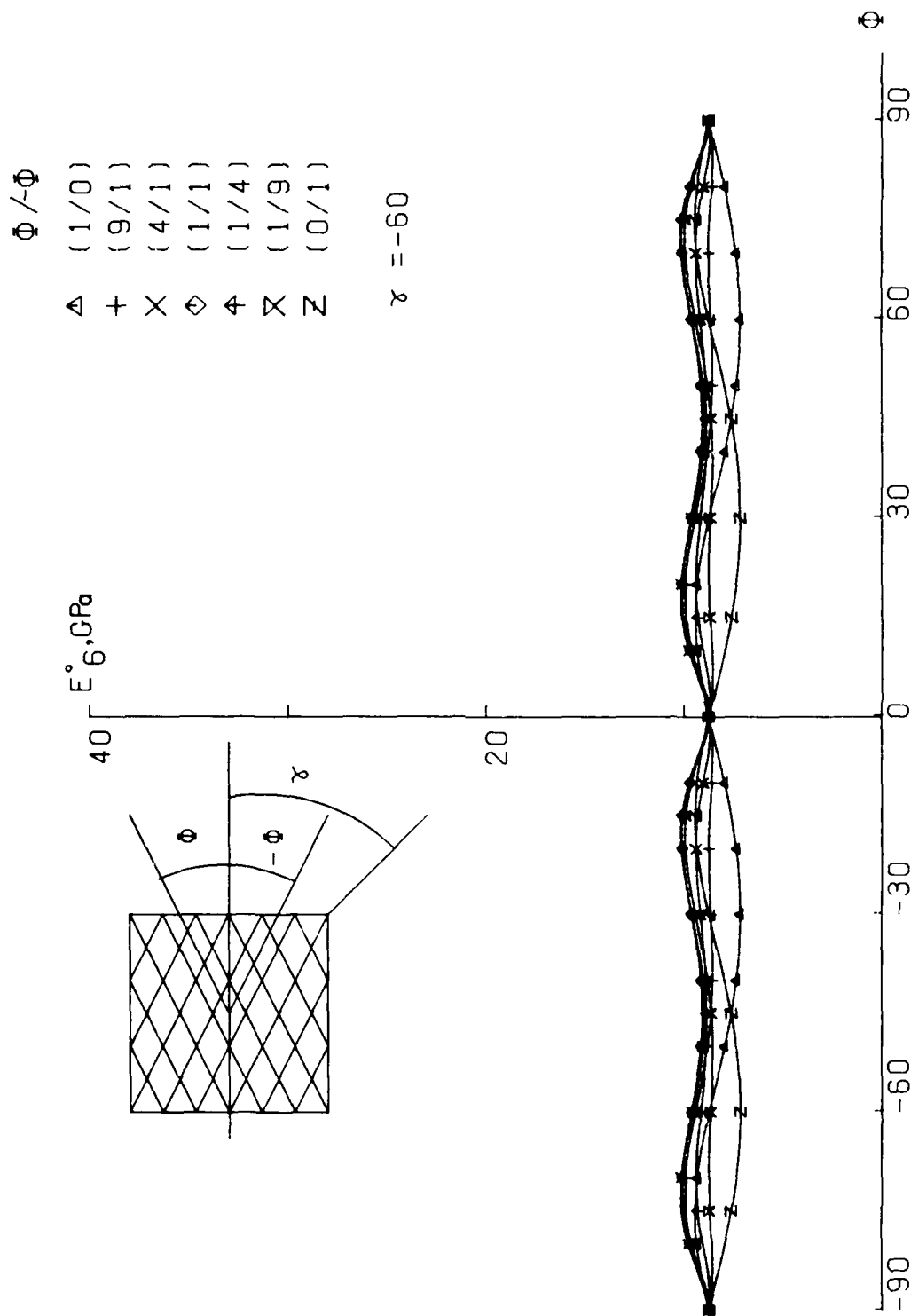


FIG.: 322

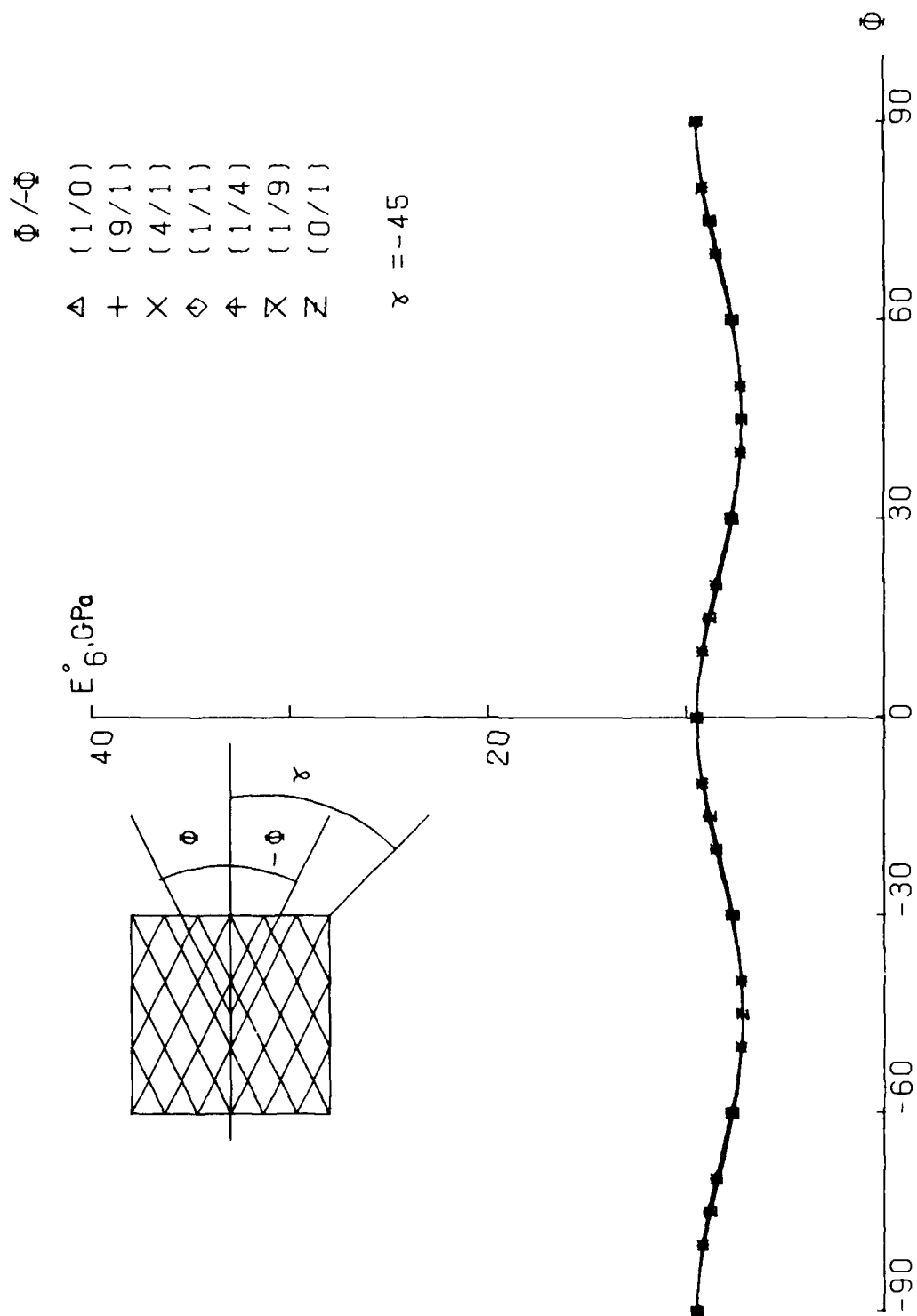


FIG.: 323

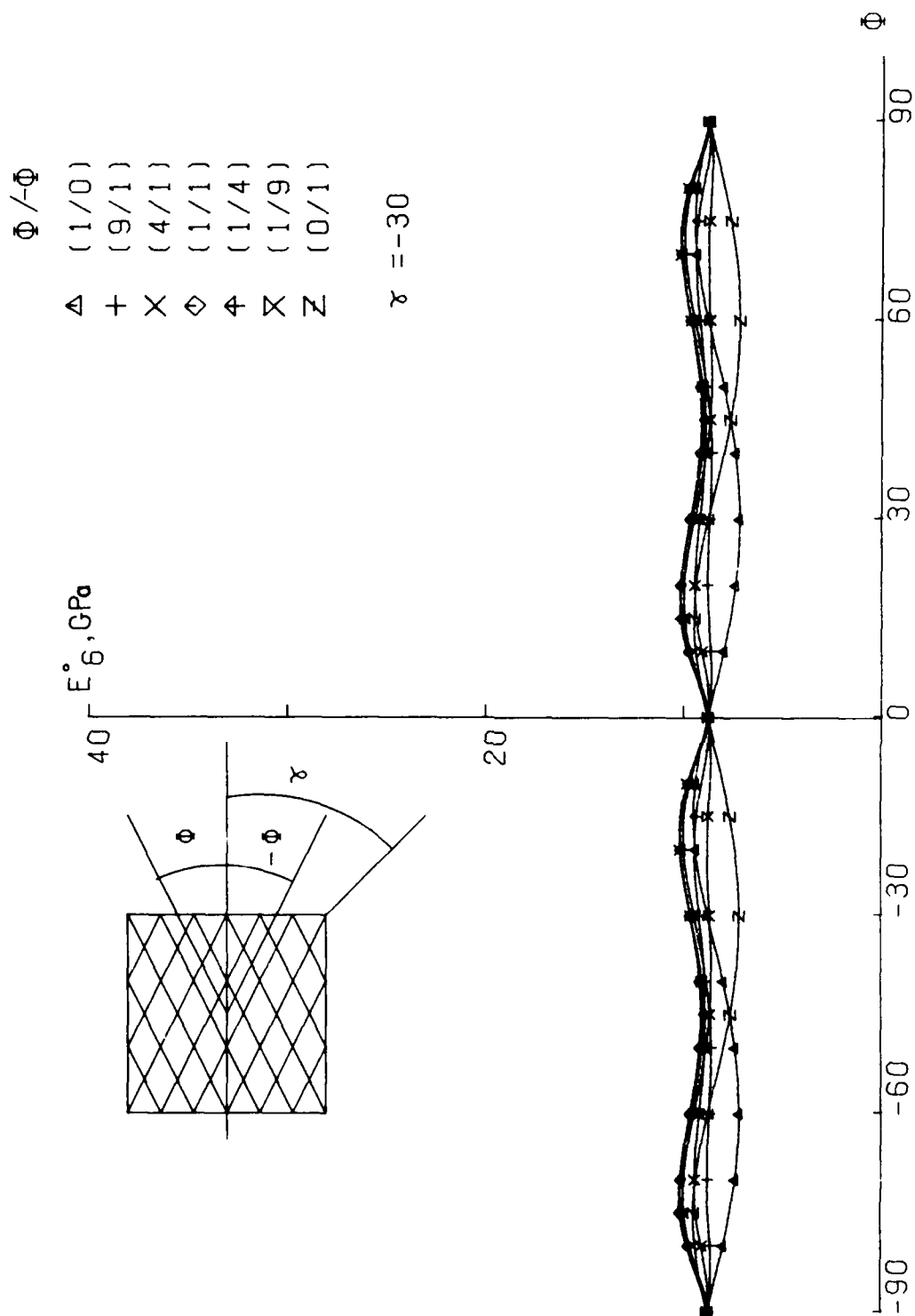


FIG.: 324

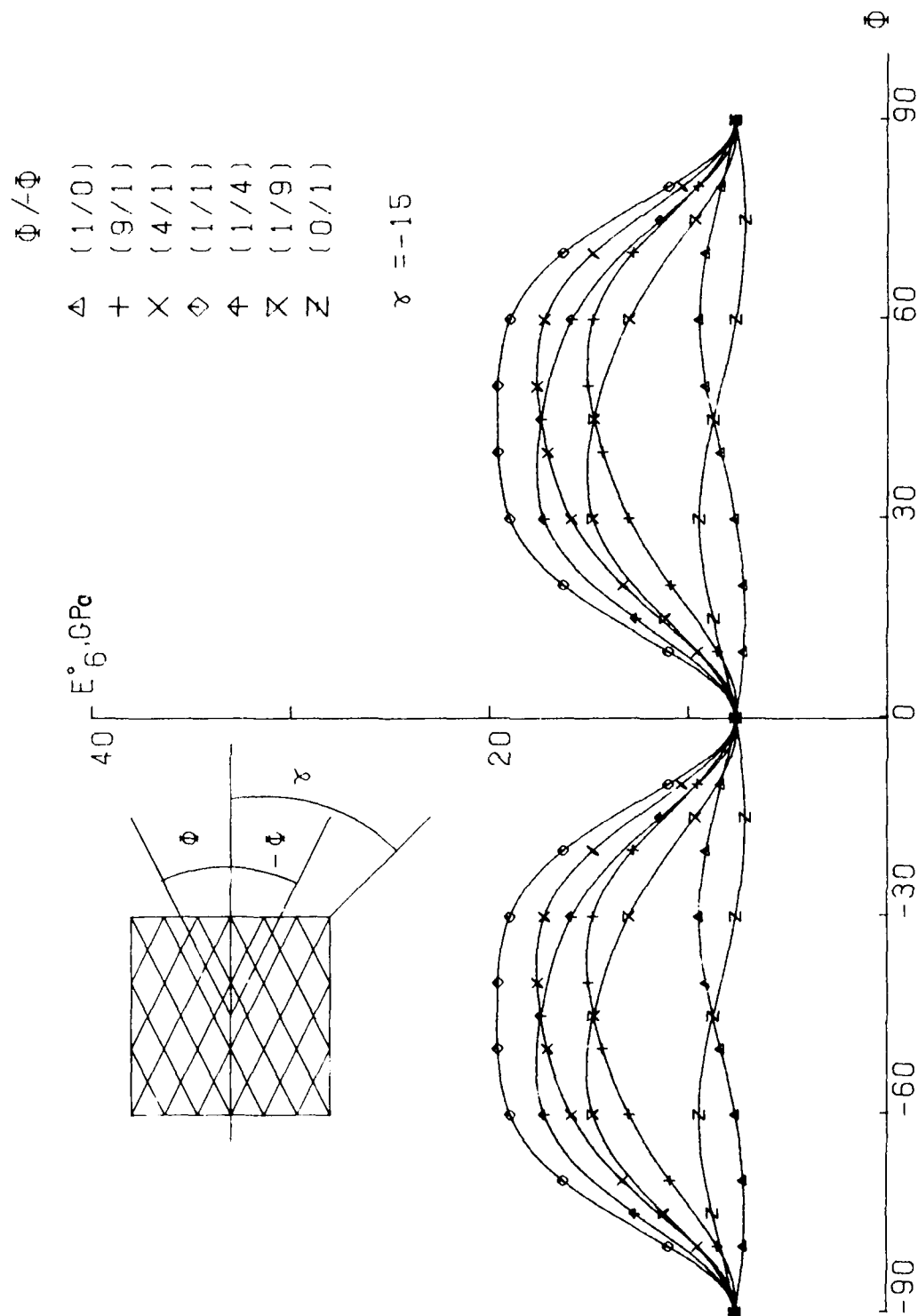


FIG.: 325

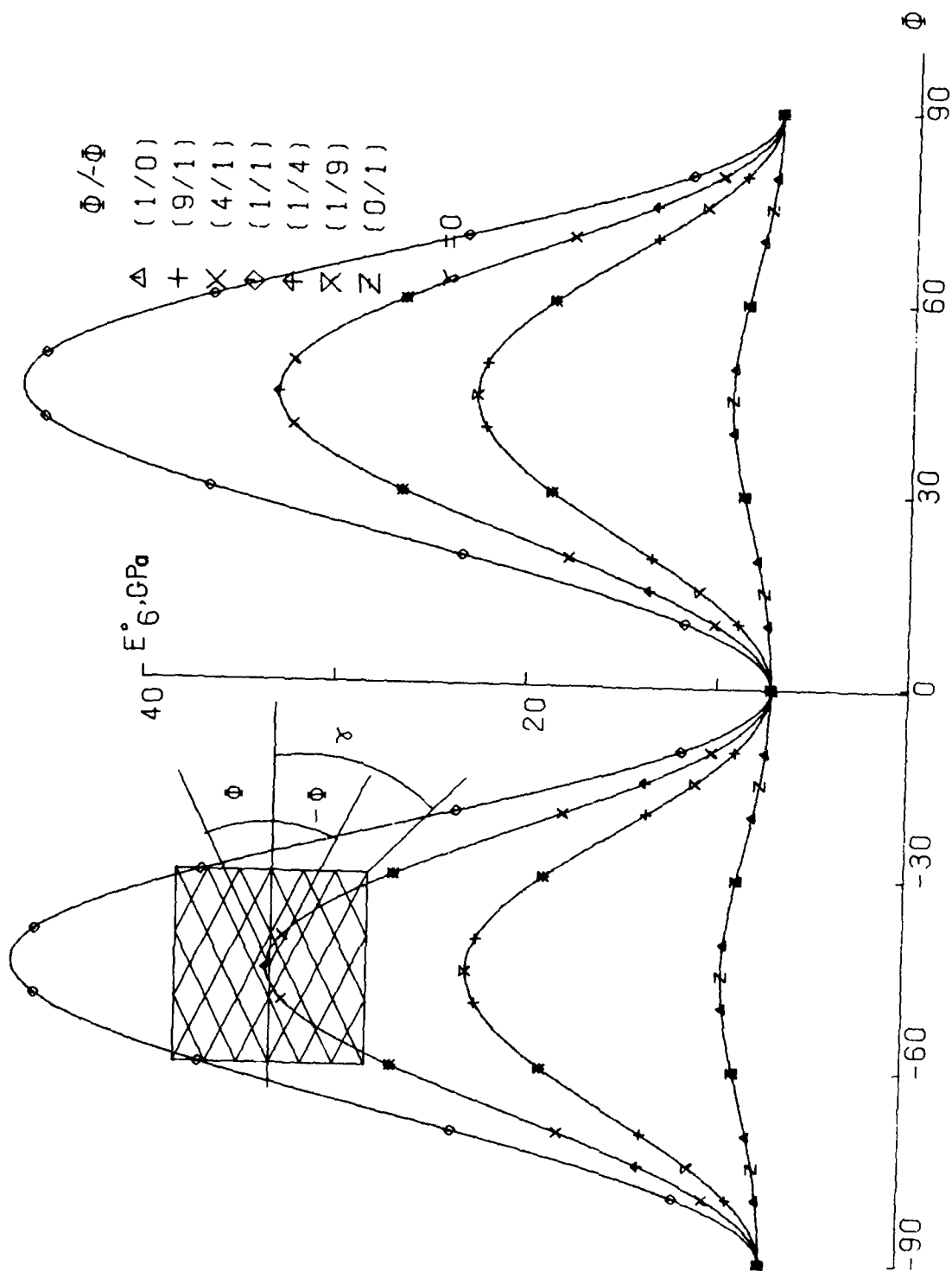


FIG.: 326

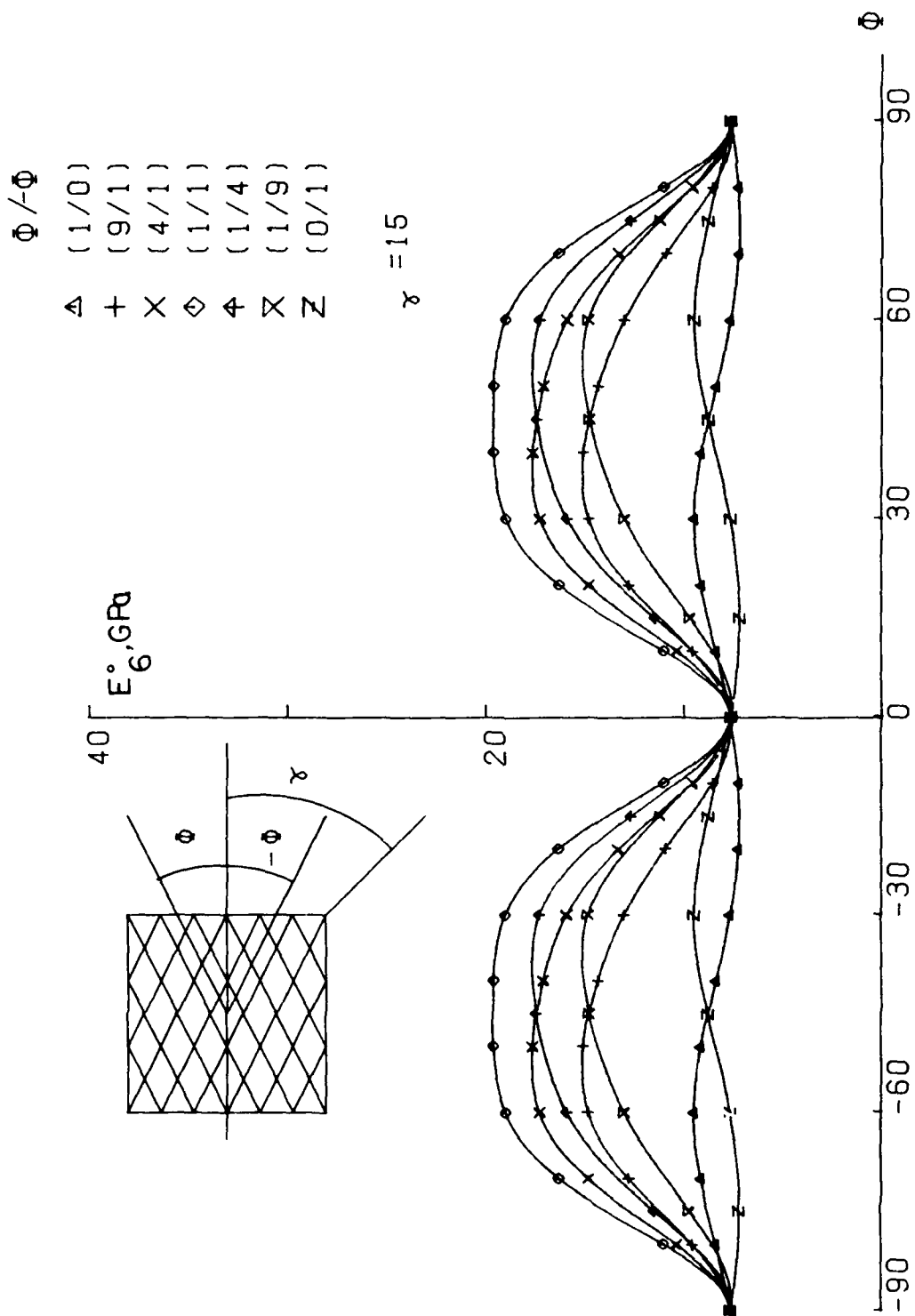


FIG.:327

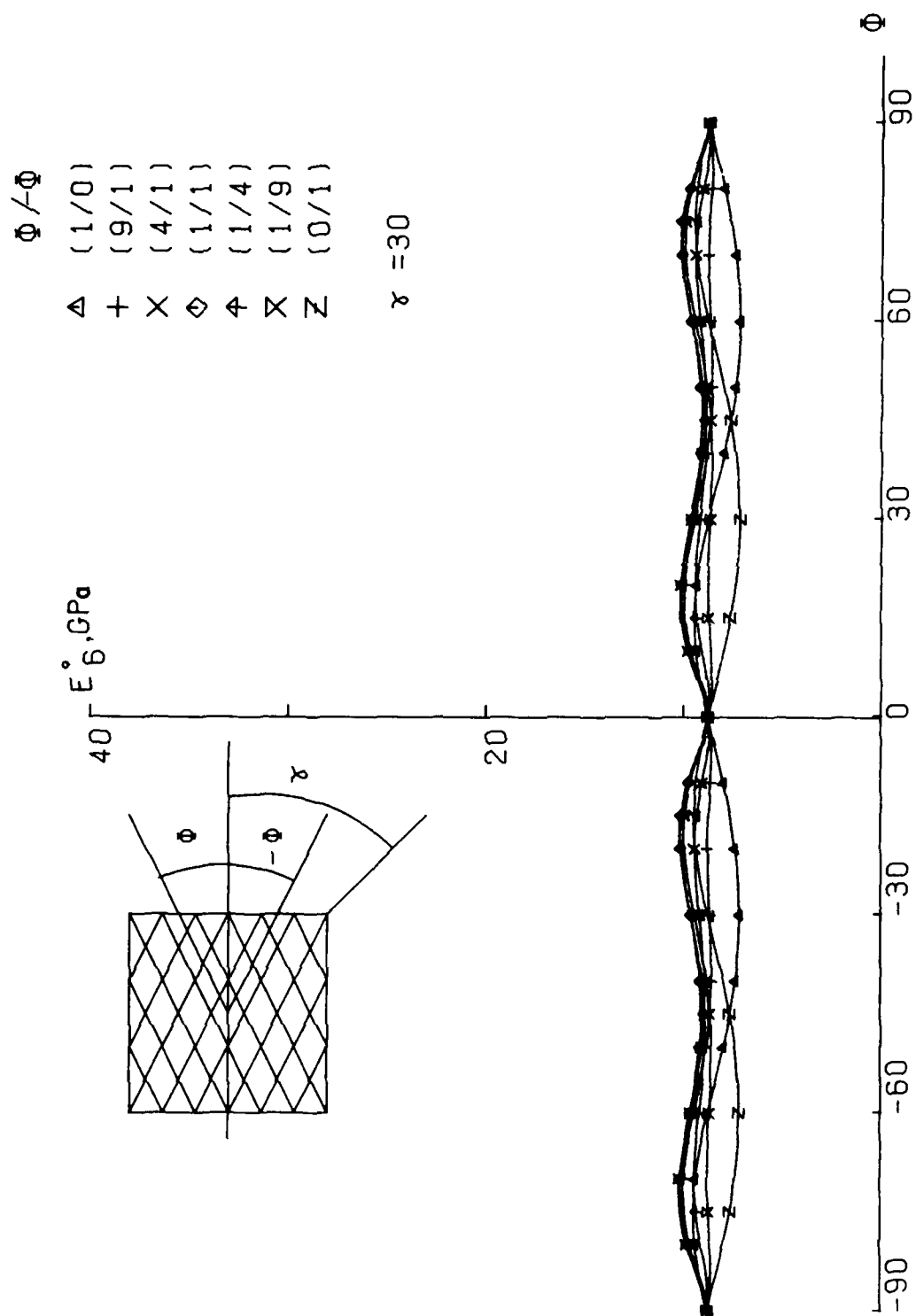


FIG.:328

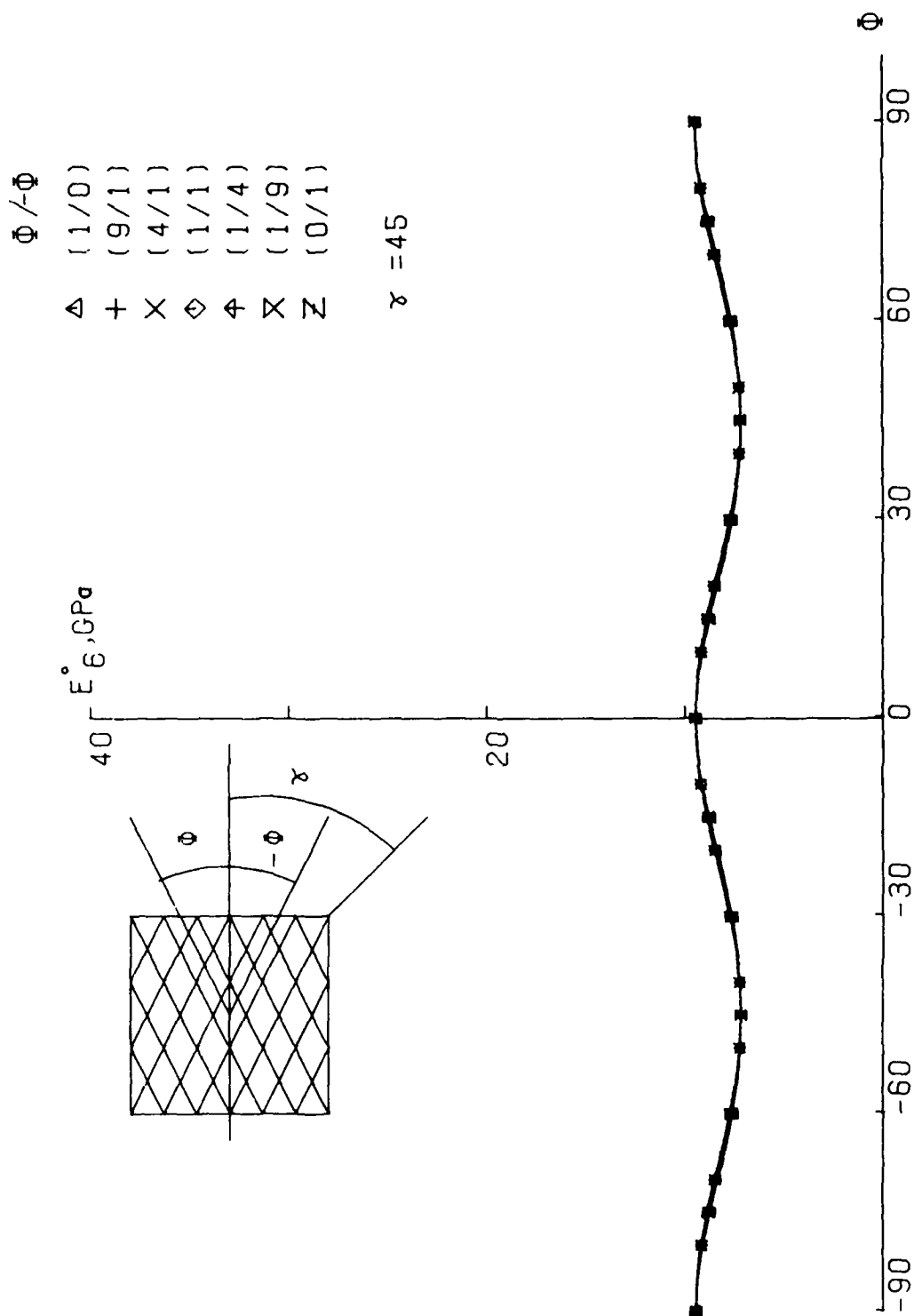


FIG.: 329

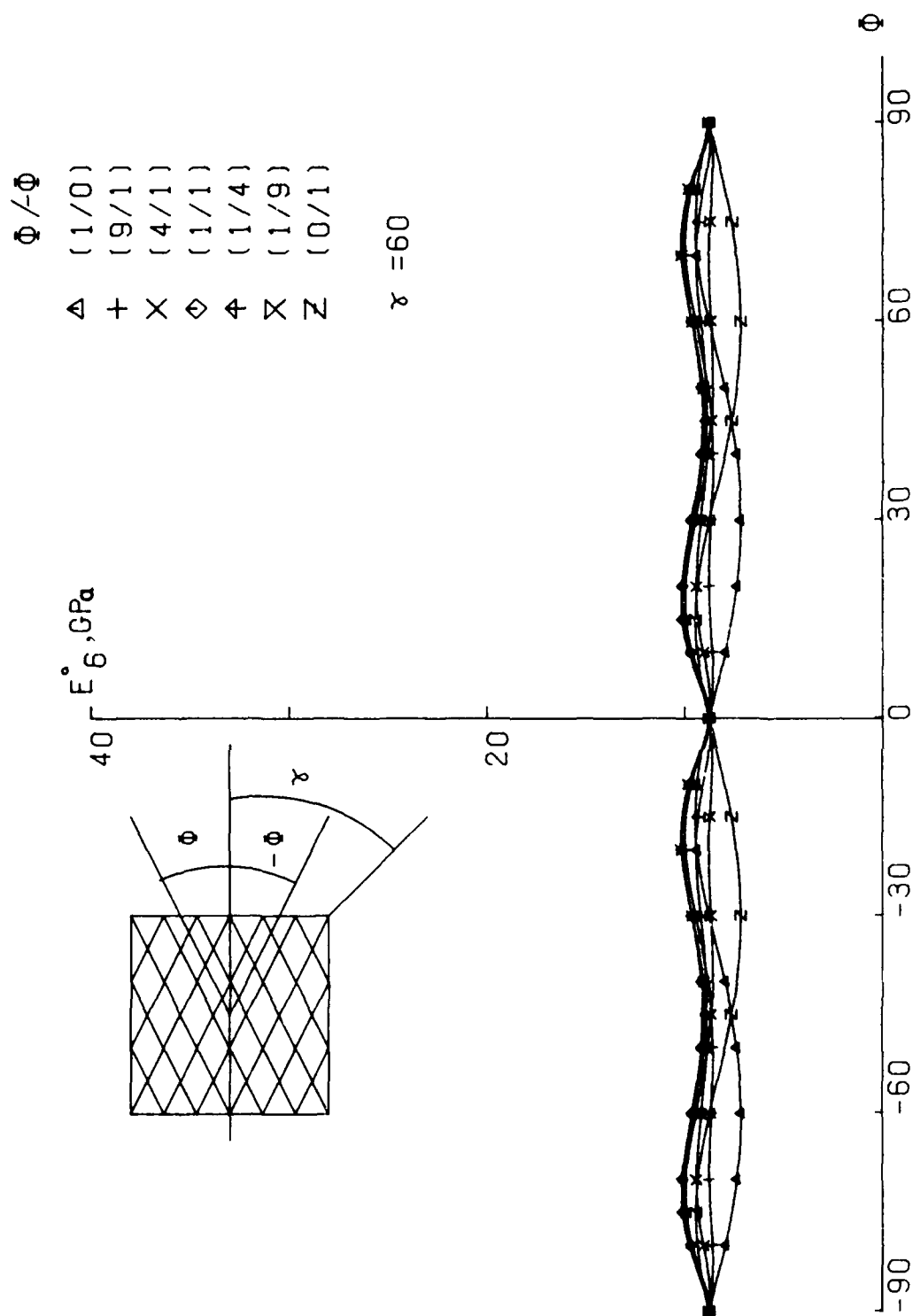


FIG.: 330

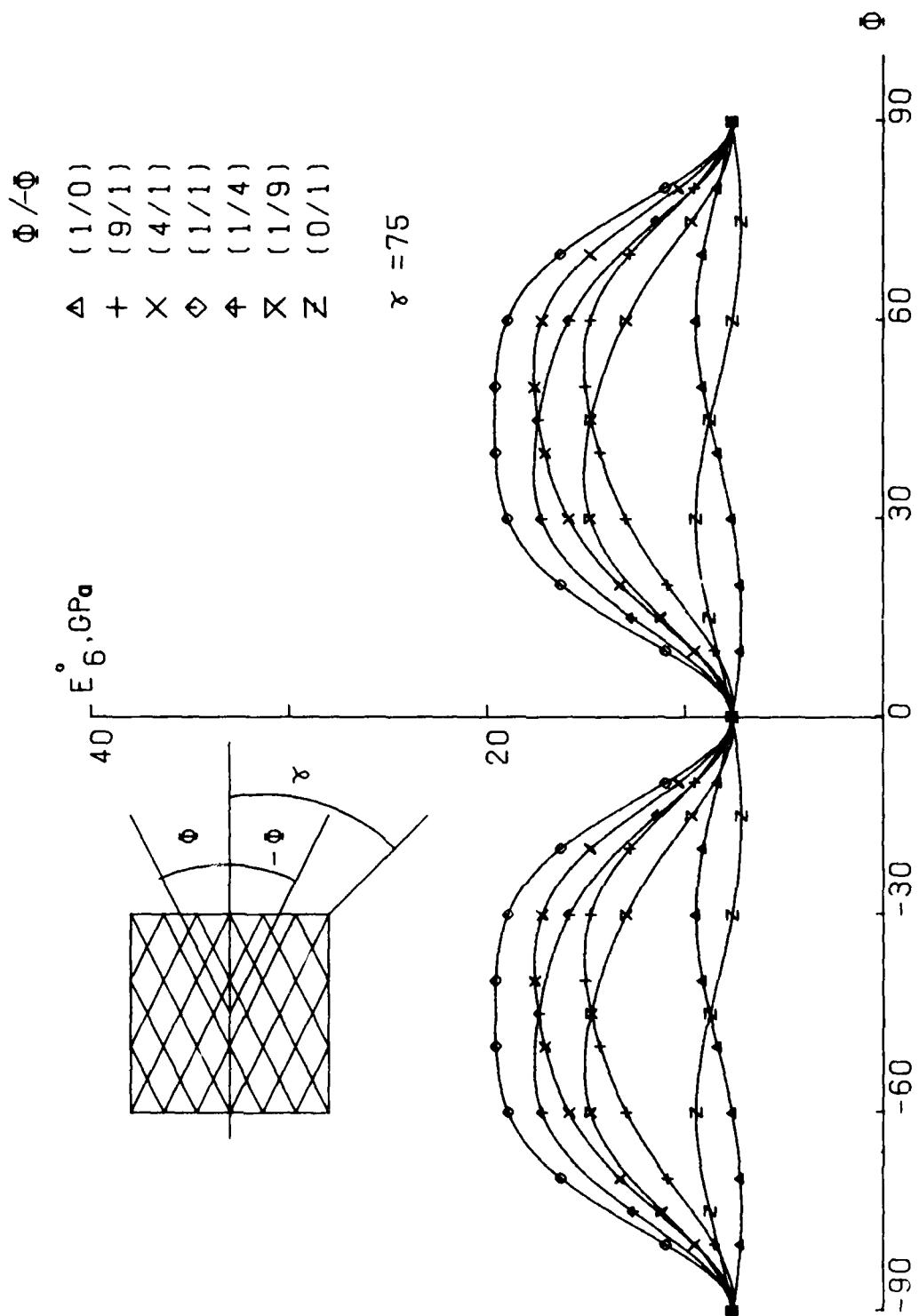


FIG.:331

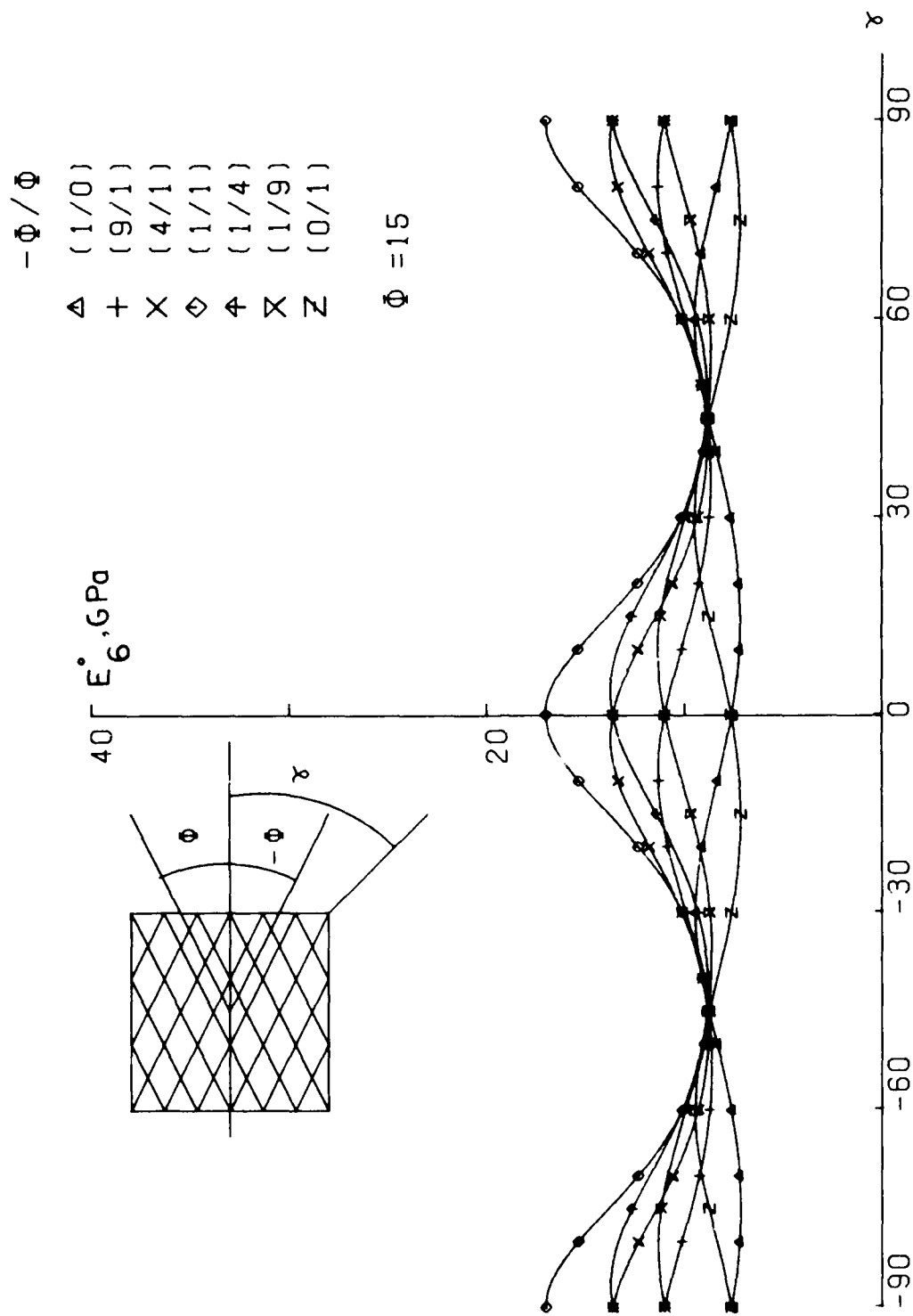


FIG.: 332

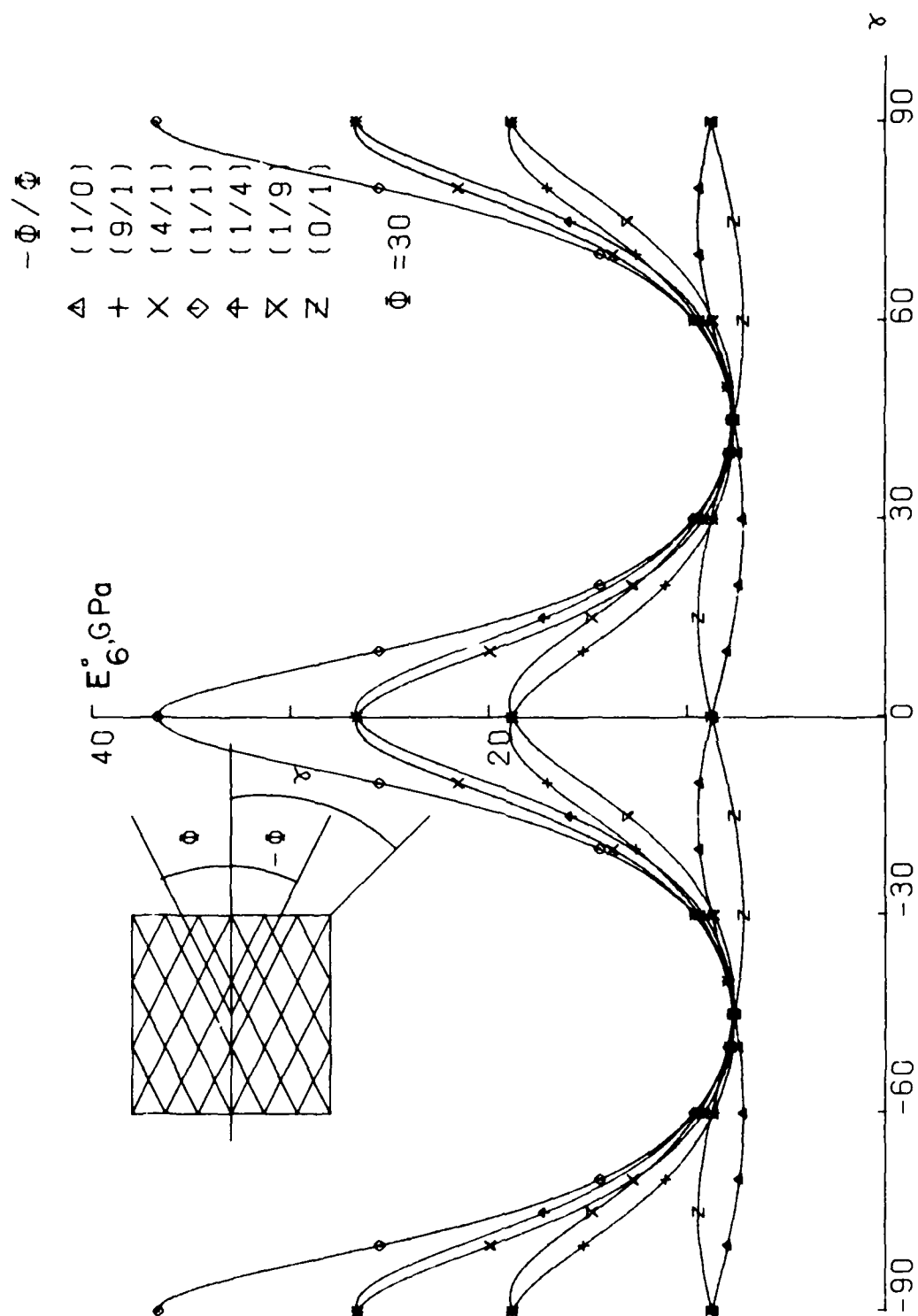


FIG.: 333

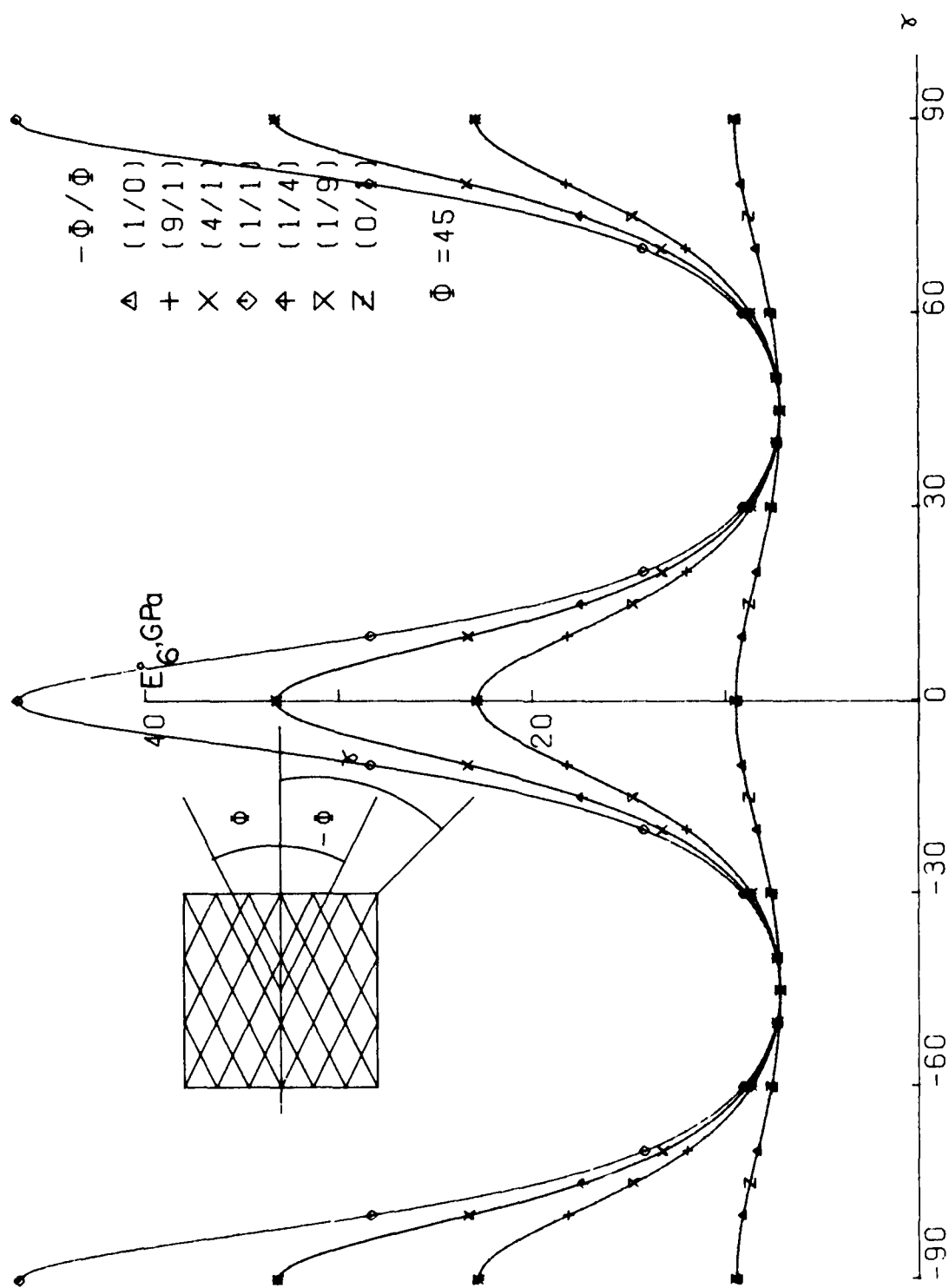


FIG.: 334

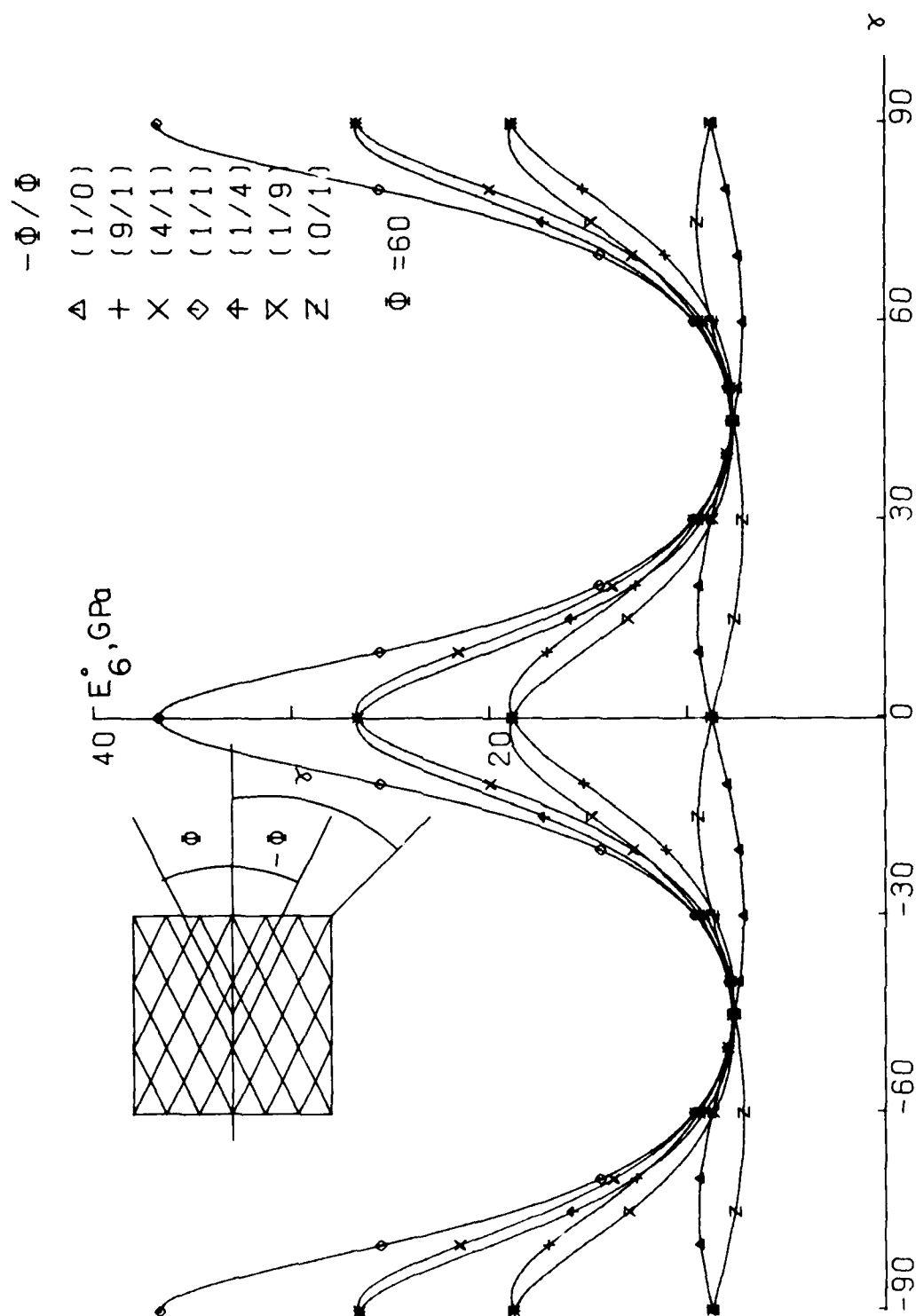


FIG.: 335

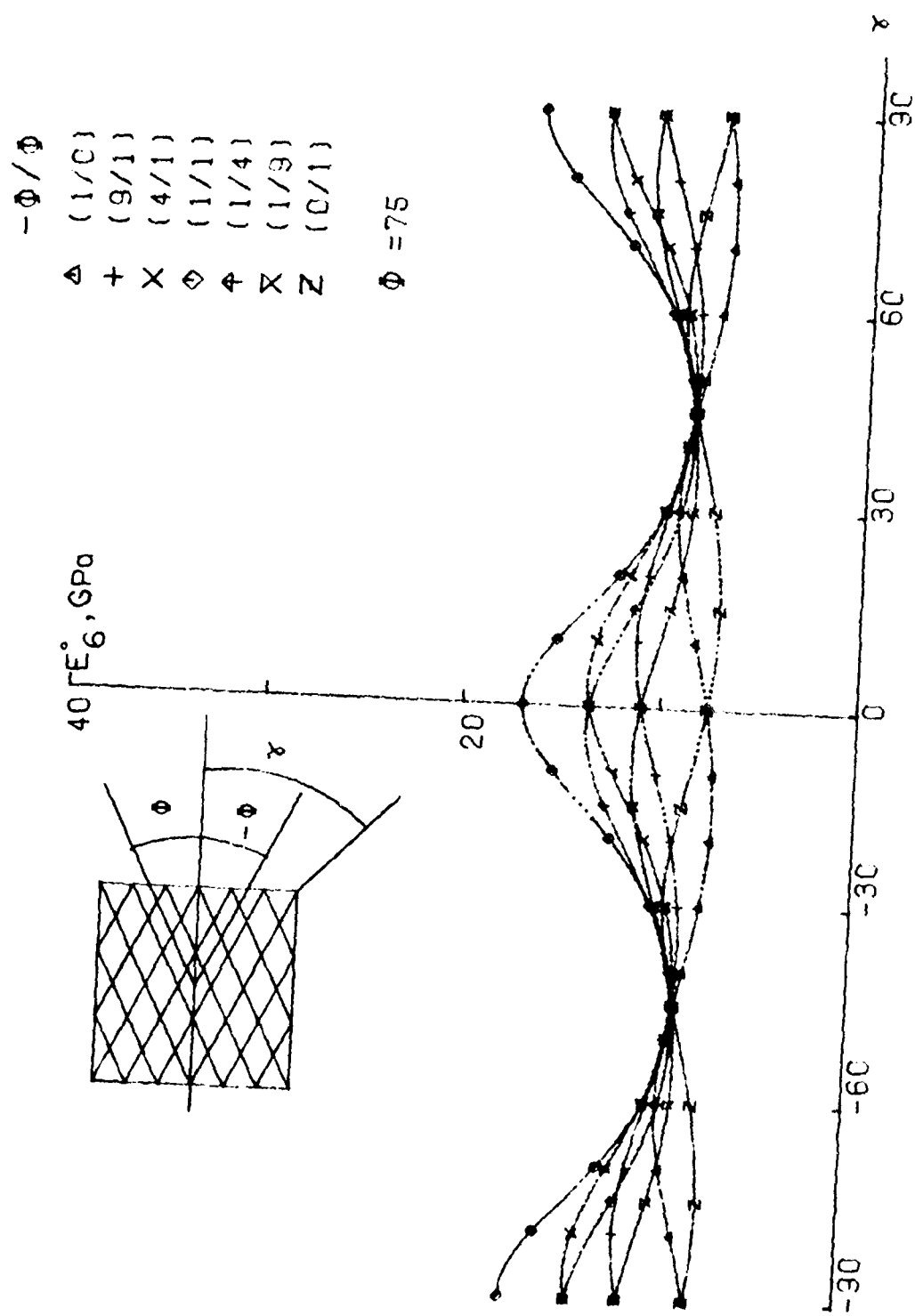


FIG.: 336

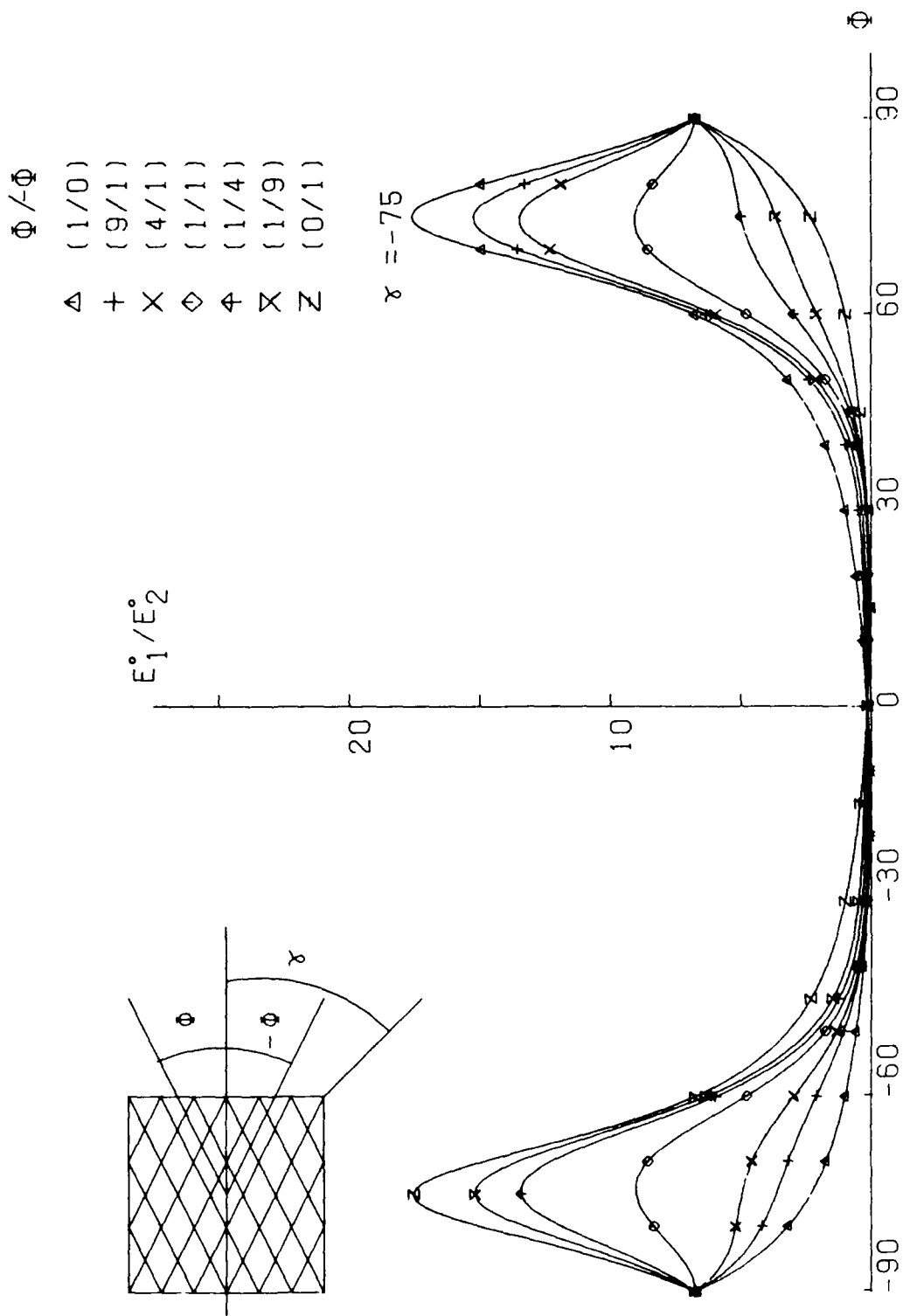


FIG.: 337

AD-A093 227 AIR FORCE WRIGHT AERONAUTICAL LABS WRIGHT-PATTERSON AFB OH F/6 11/4
ELASTIC PROPERTIES OF T300/5208 BIDIRECTIONAL SYMMETRIC LAMINAT--ETC(U)
SEP 80 S R SONI
UNCLASSIFIED AFWL-TR-80-4111 NL

AIR FORCE WRIGHT AERONAUTICAL LABS WRIGHT-PATTERSON AFB OH F/G 11/4
ELASTIC PROPERTIES OF T300/5208 BIDIRECTIONAL SYMMETRIC LAMINAT--ETC(U)
SEP 80 S R SONI
AFWAL-TR-80-4111
ML

NL

UNCLASSIFIED

545

9.3.2.2

END
DATE
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1-8
DTIC

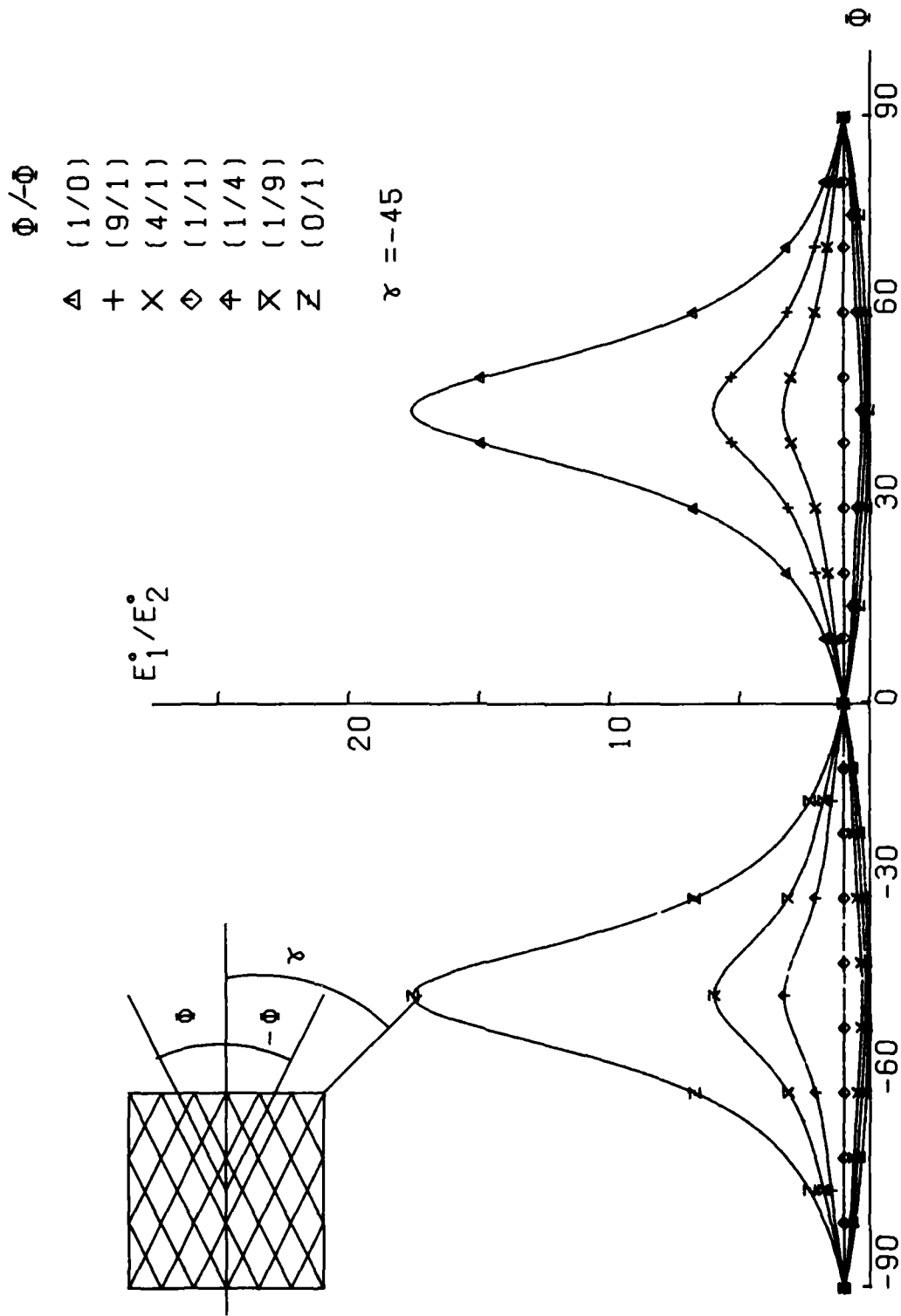


FIG.: 339

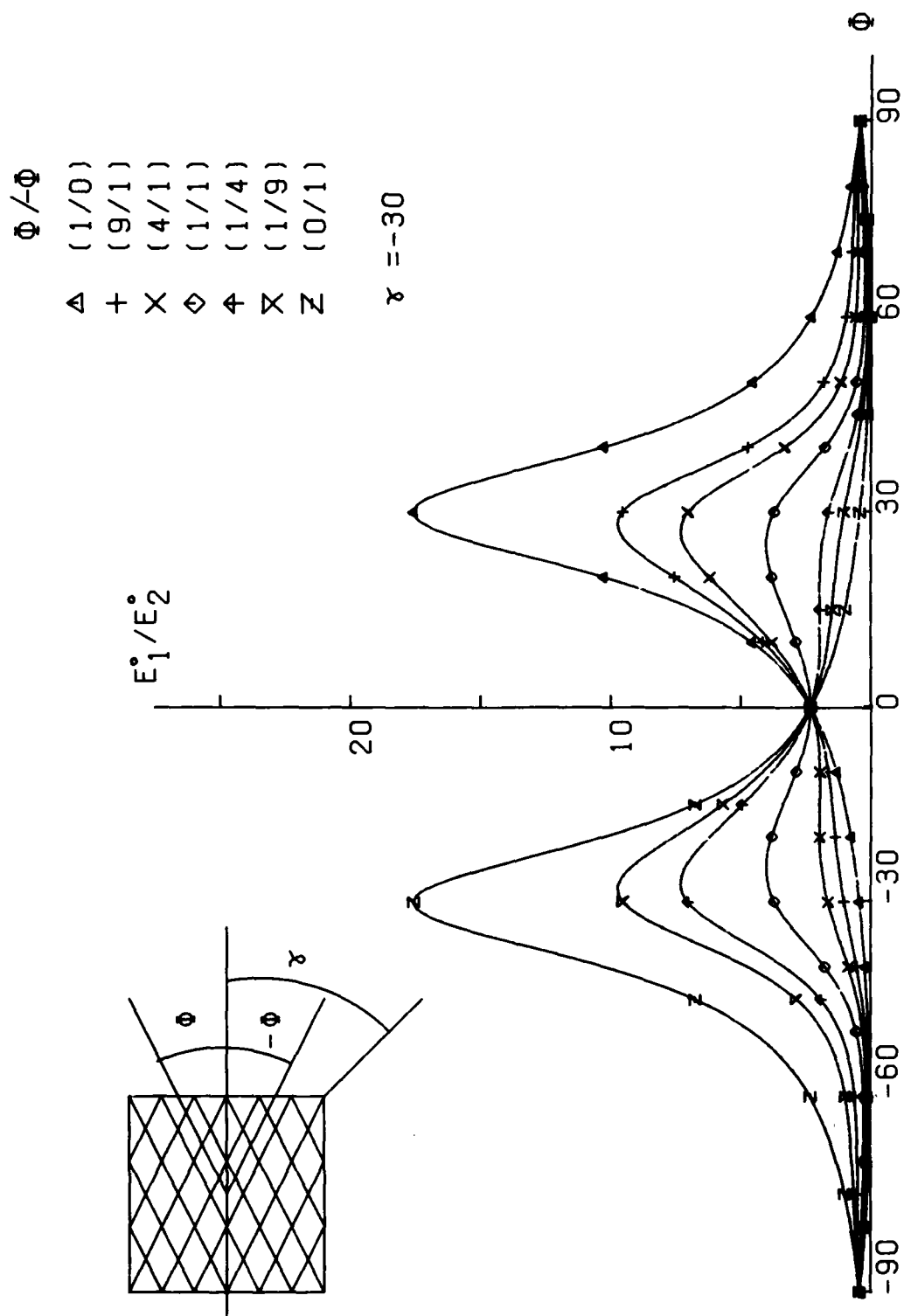


FIG.: 340

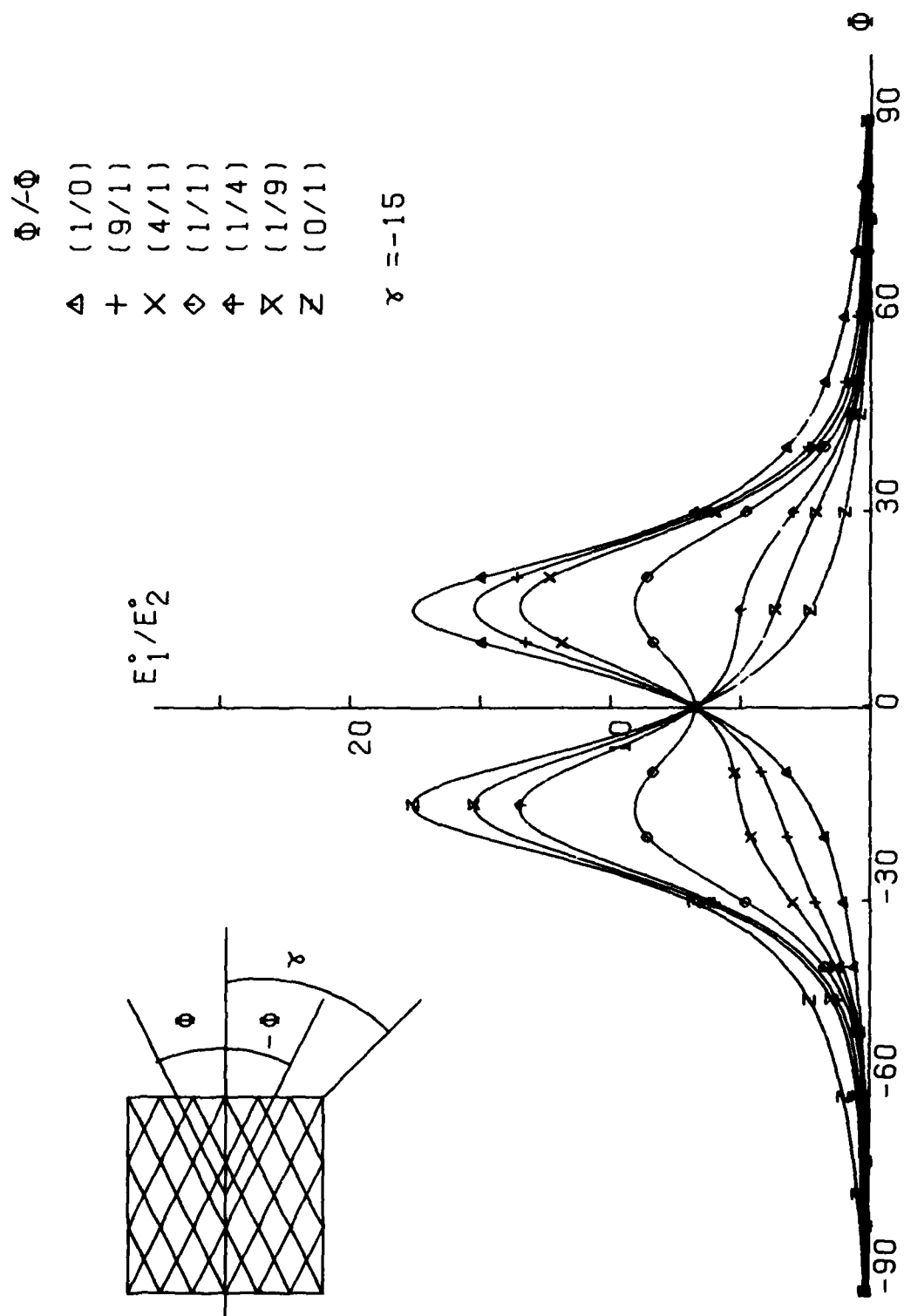


FIG.:341

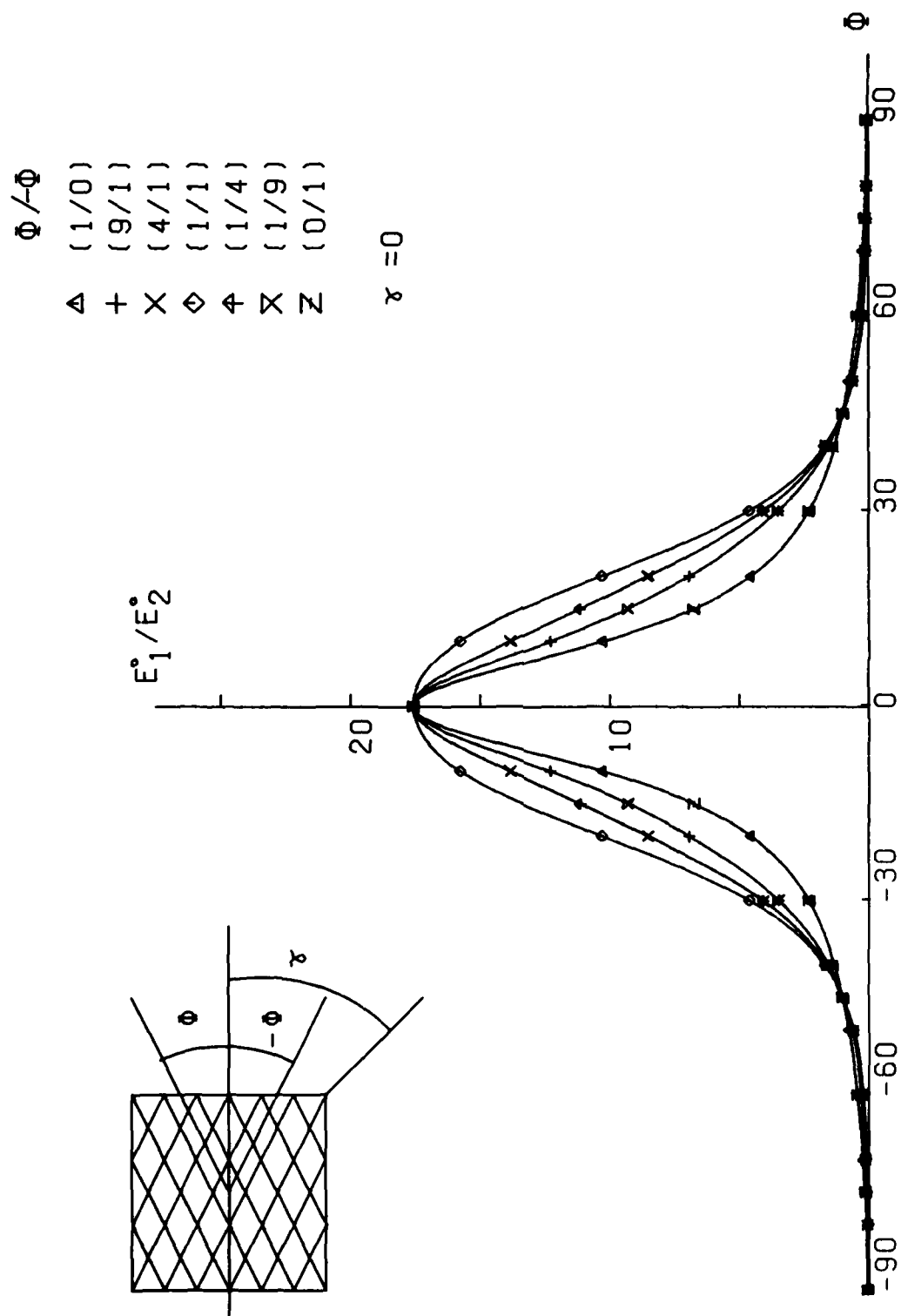


FIG.: 342

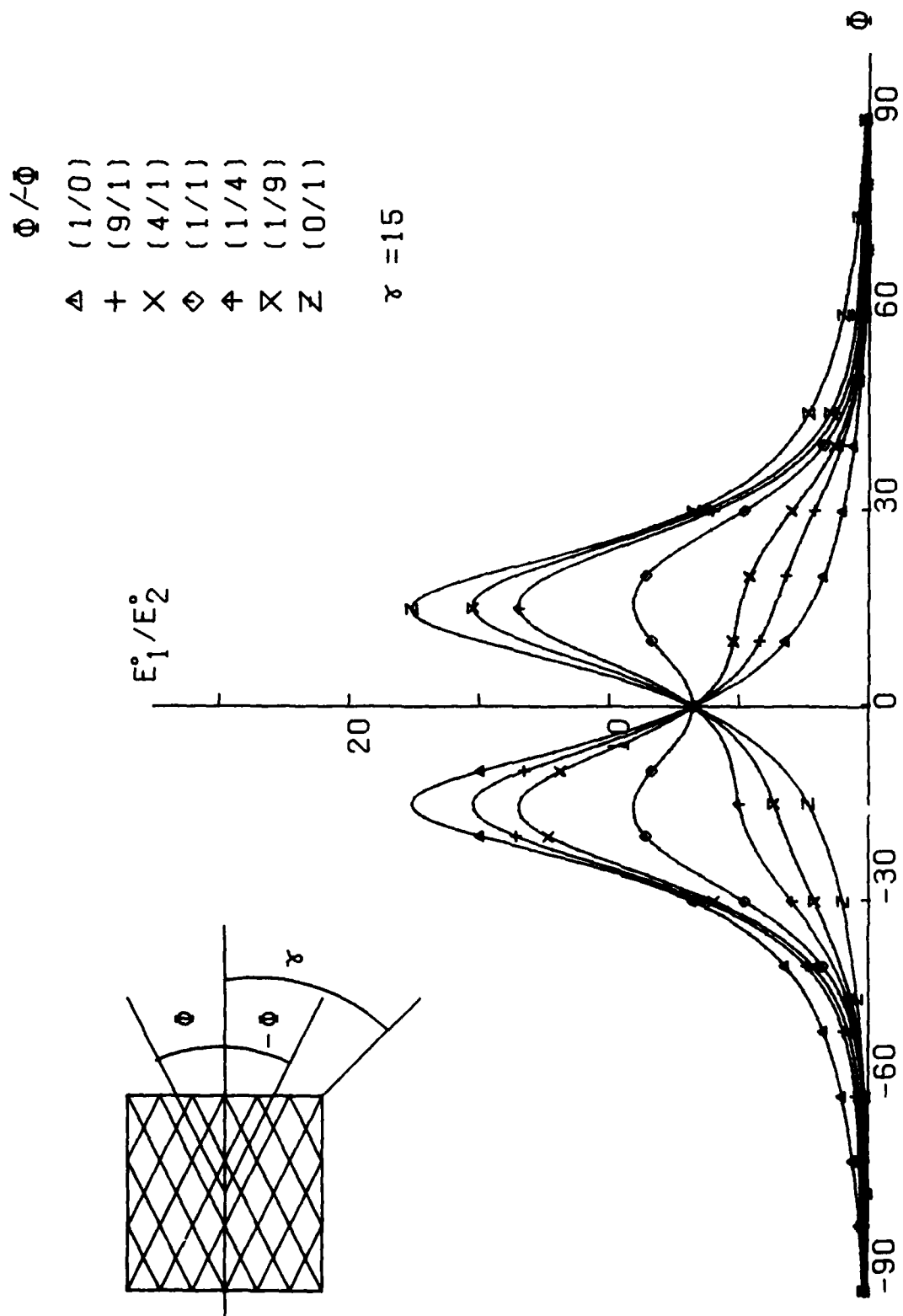
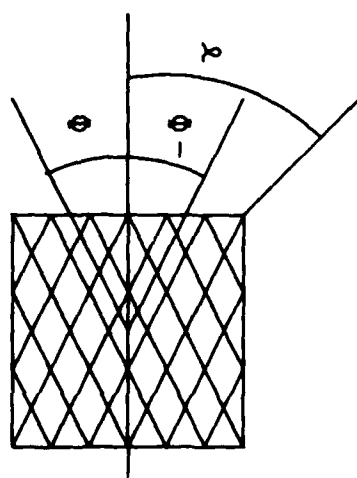


FIG.: 343



ϕ/ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)

$\chi = 30$

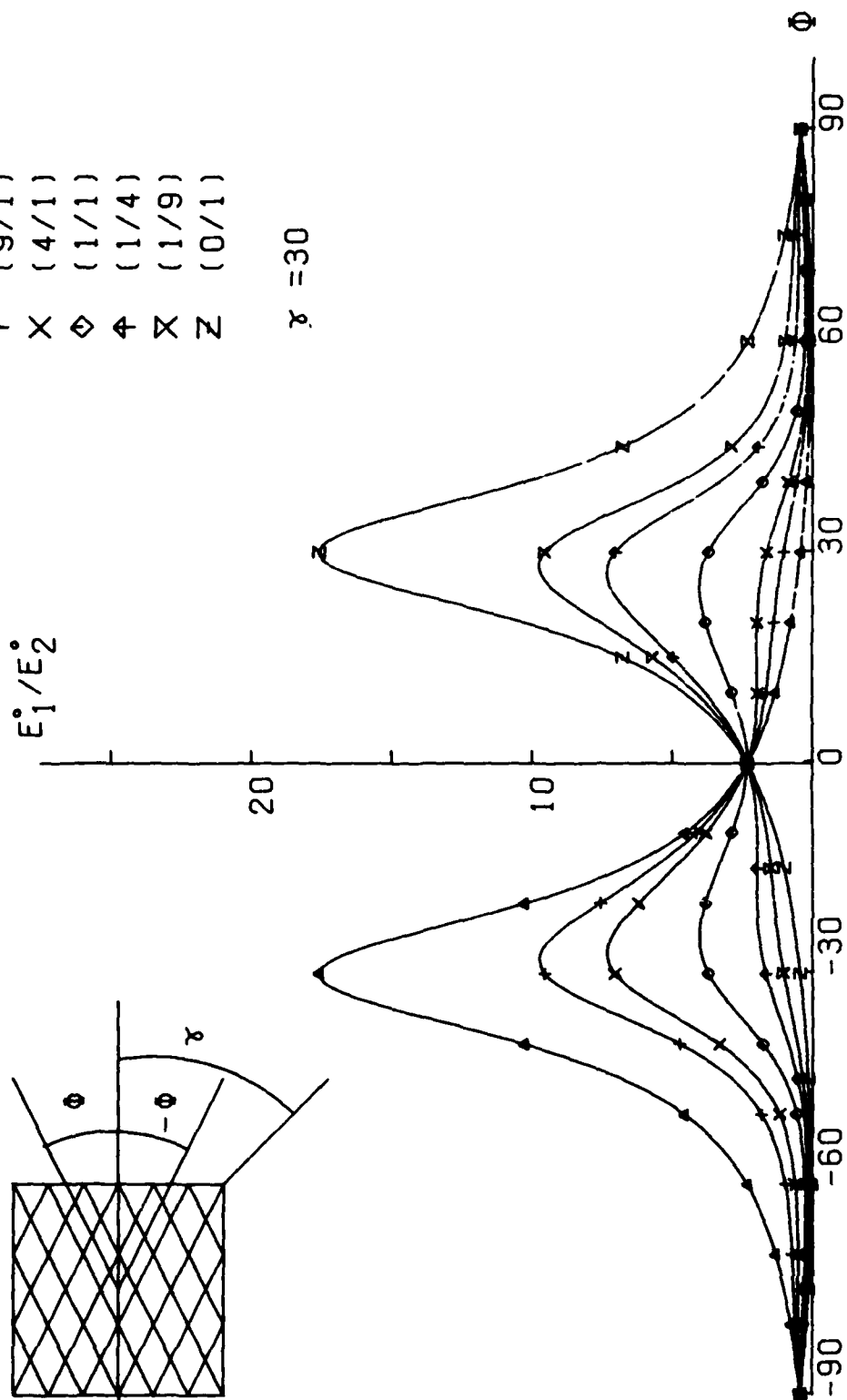


FIG.:344

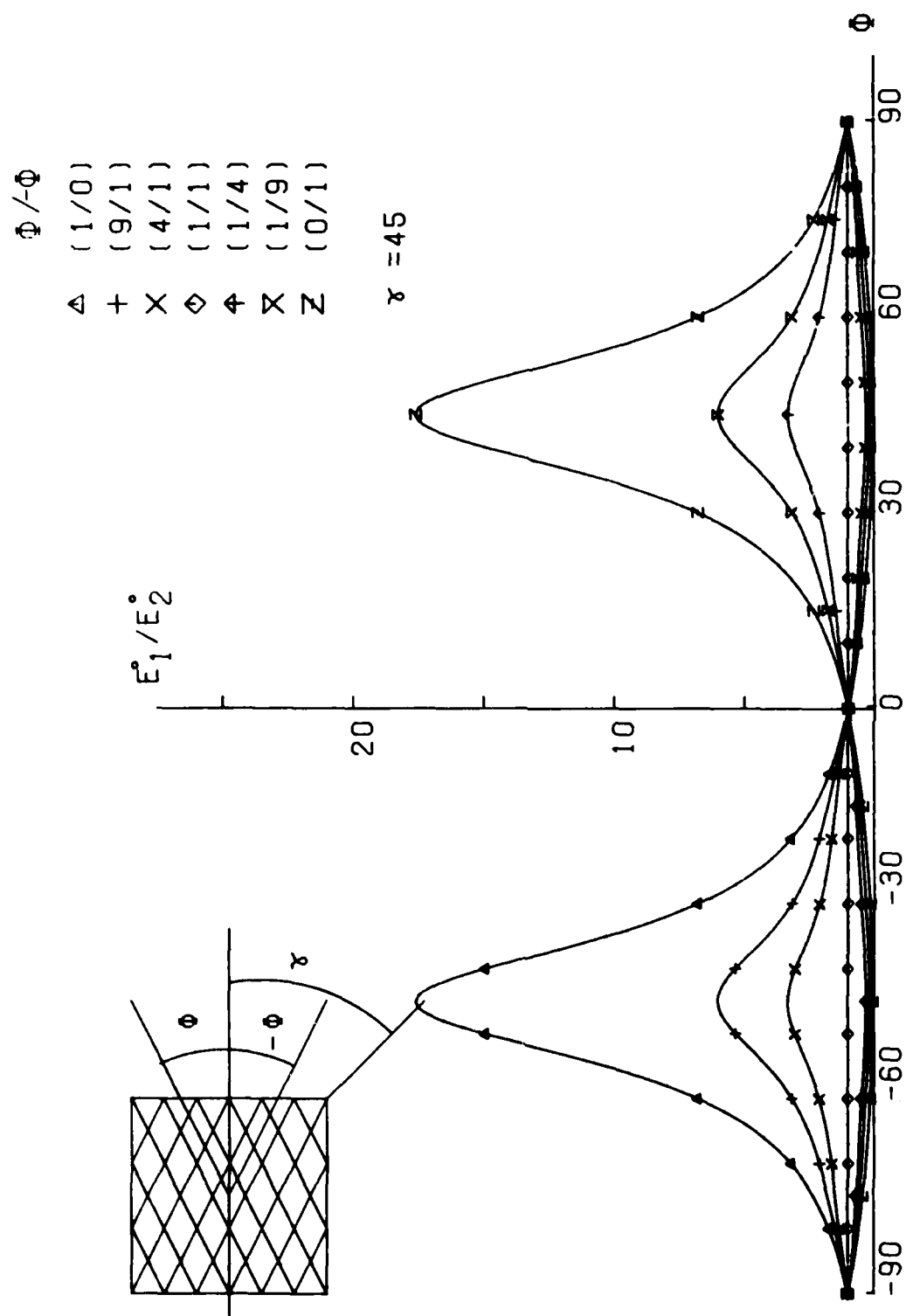


FIG.: 345

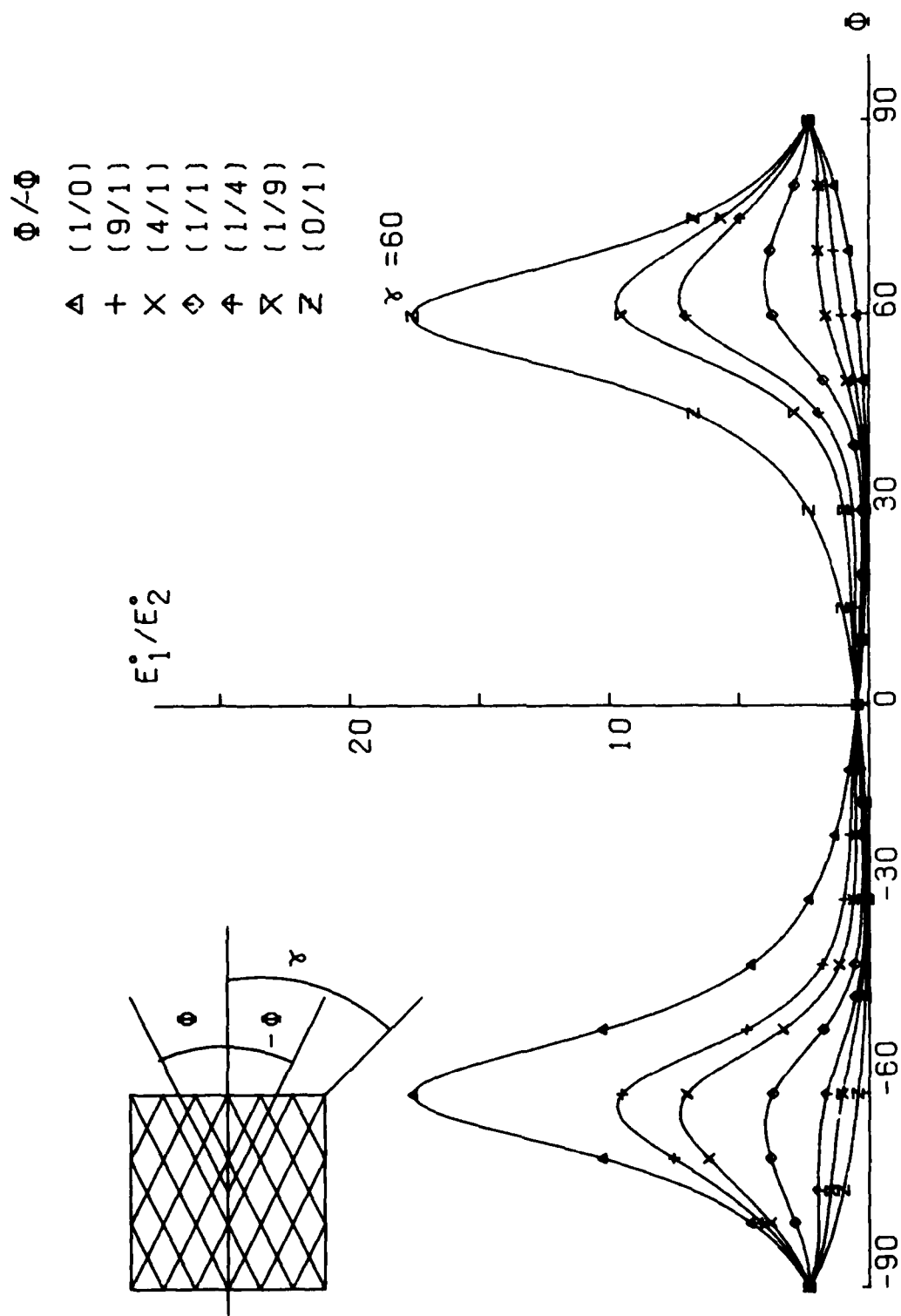


FIG.: 346

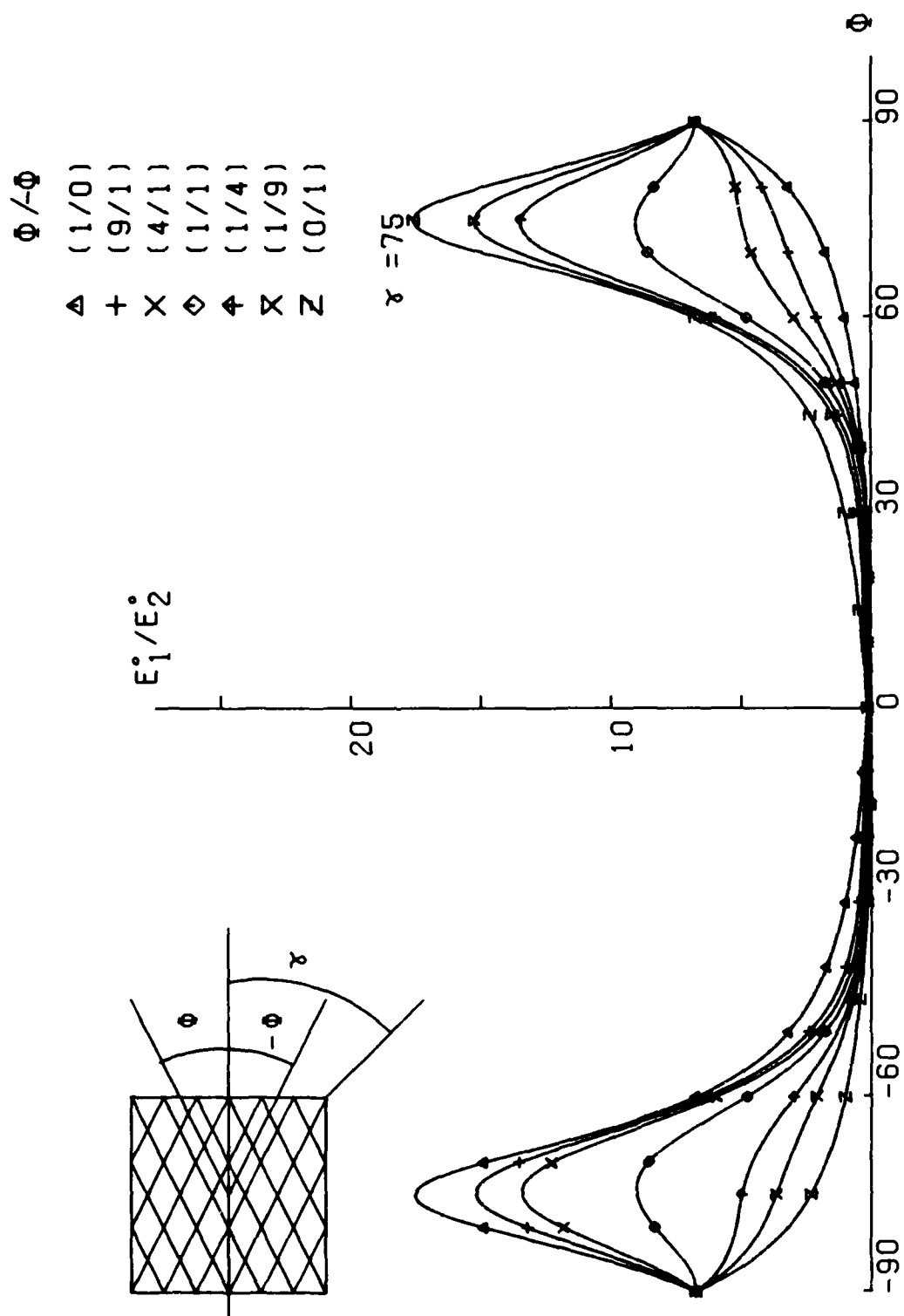


FIG.: 347

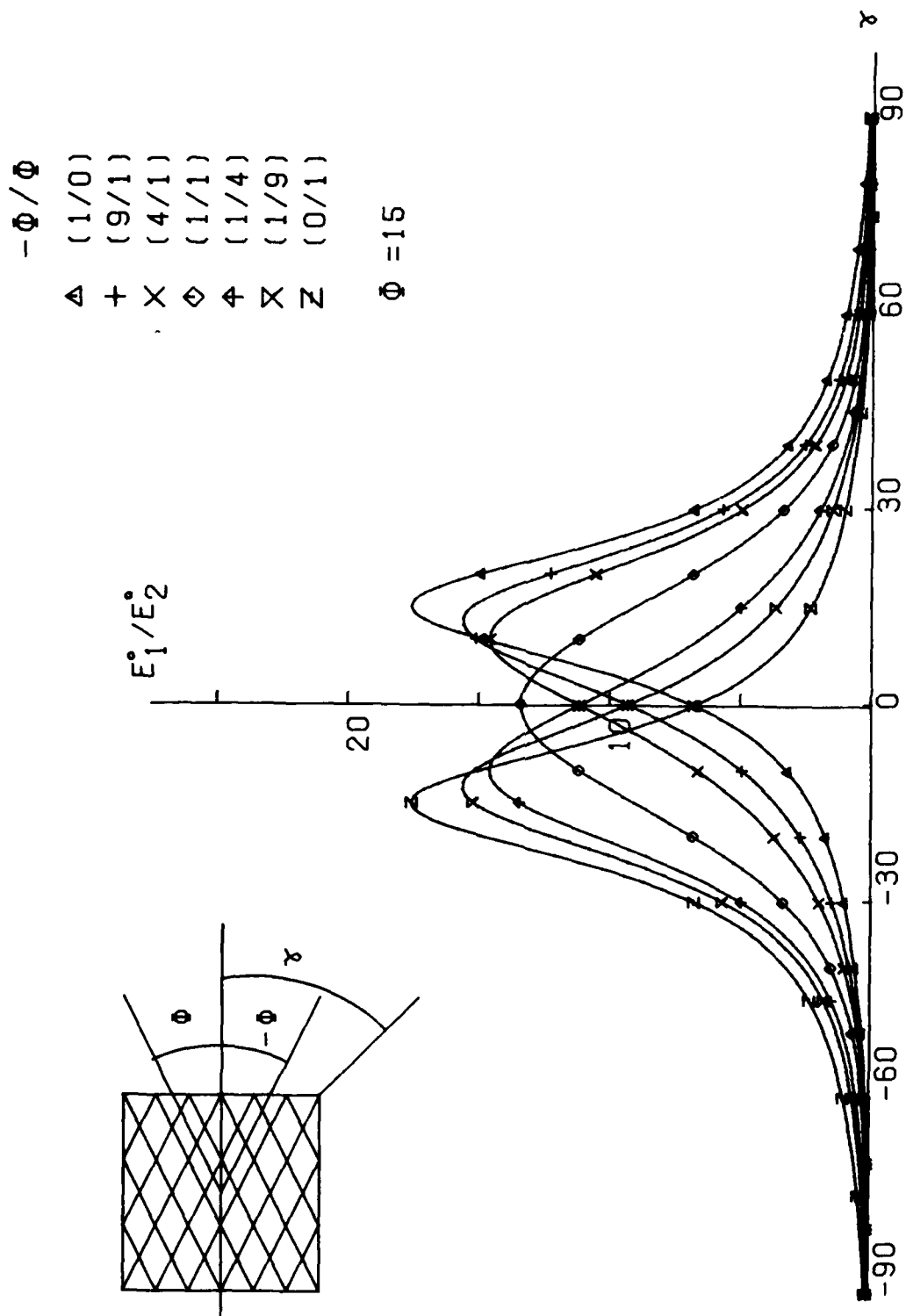
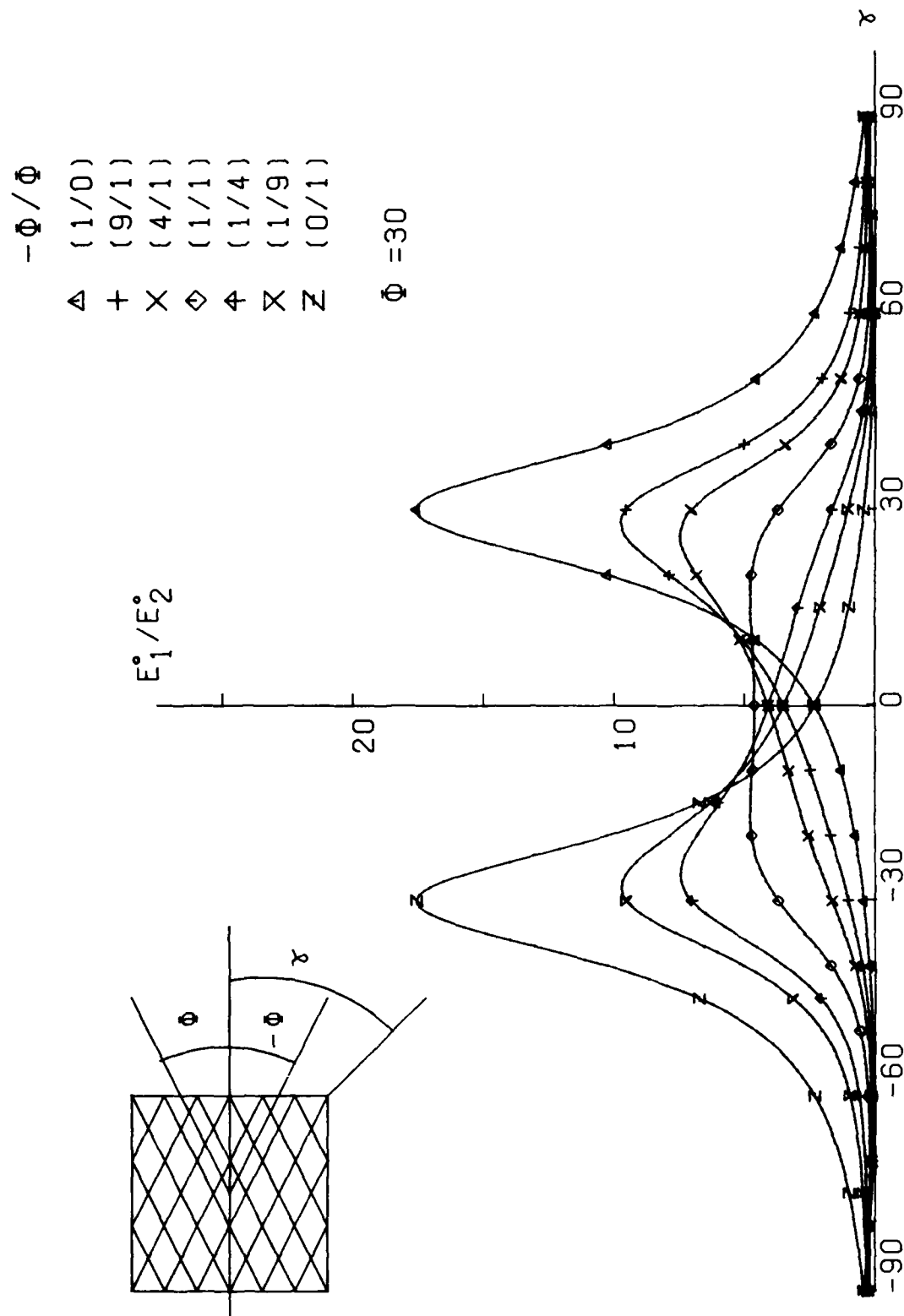


FIG.: 348



$\Phi = 30$

FIG.:349

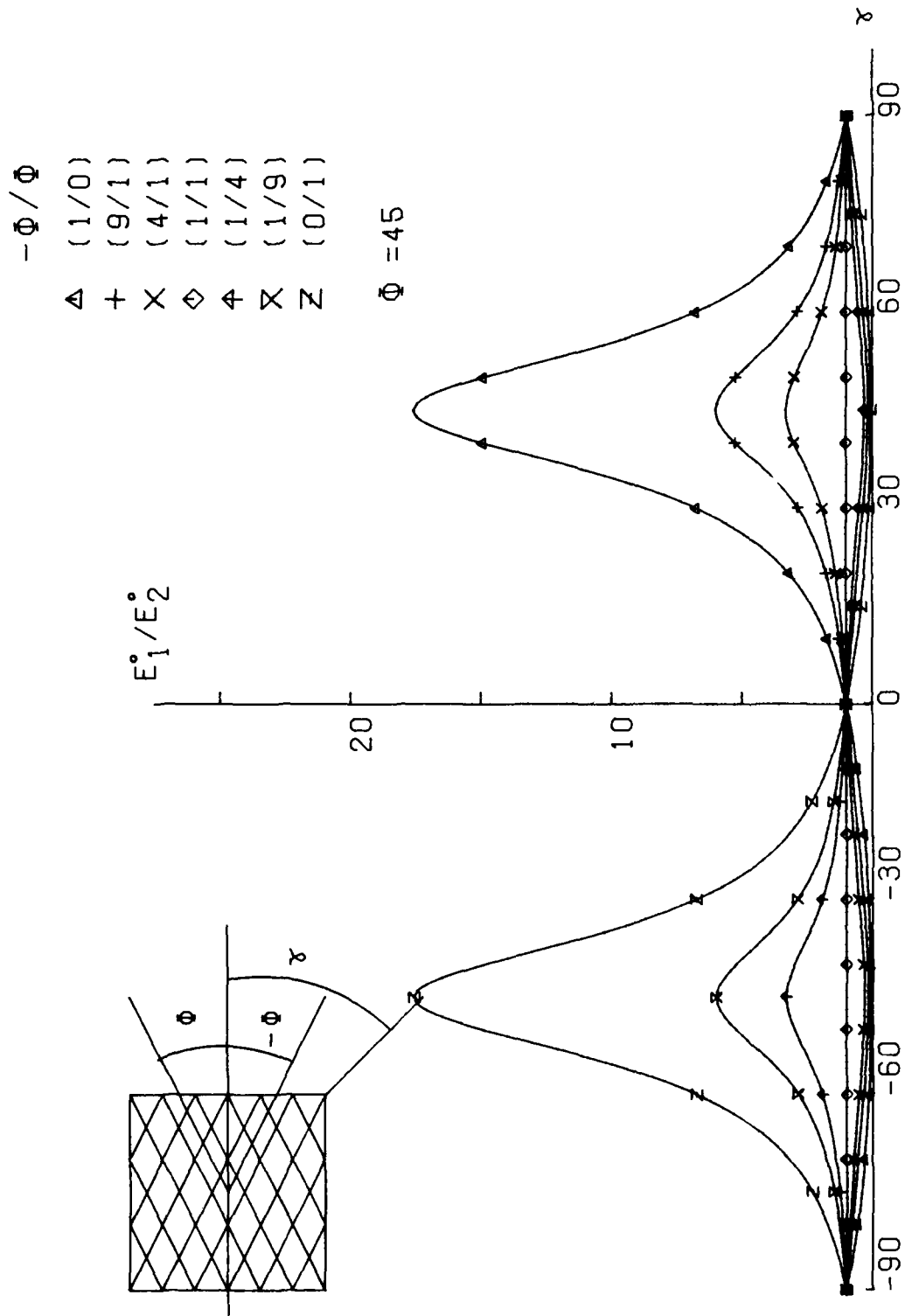


FIG.: 350

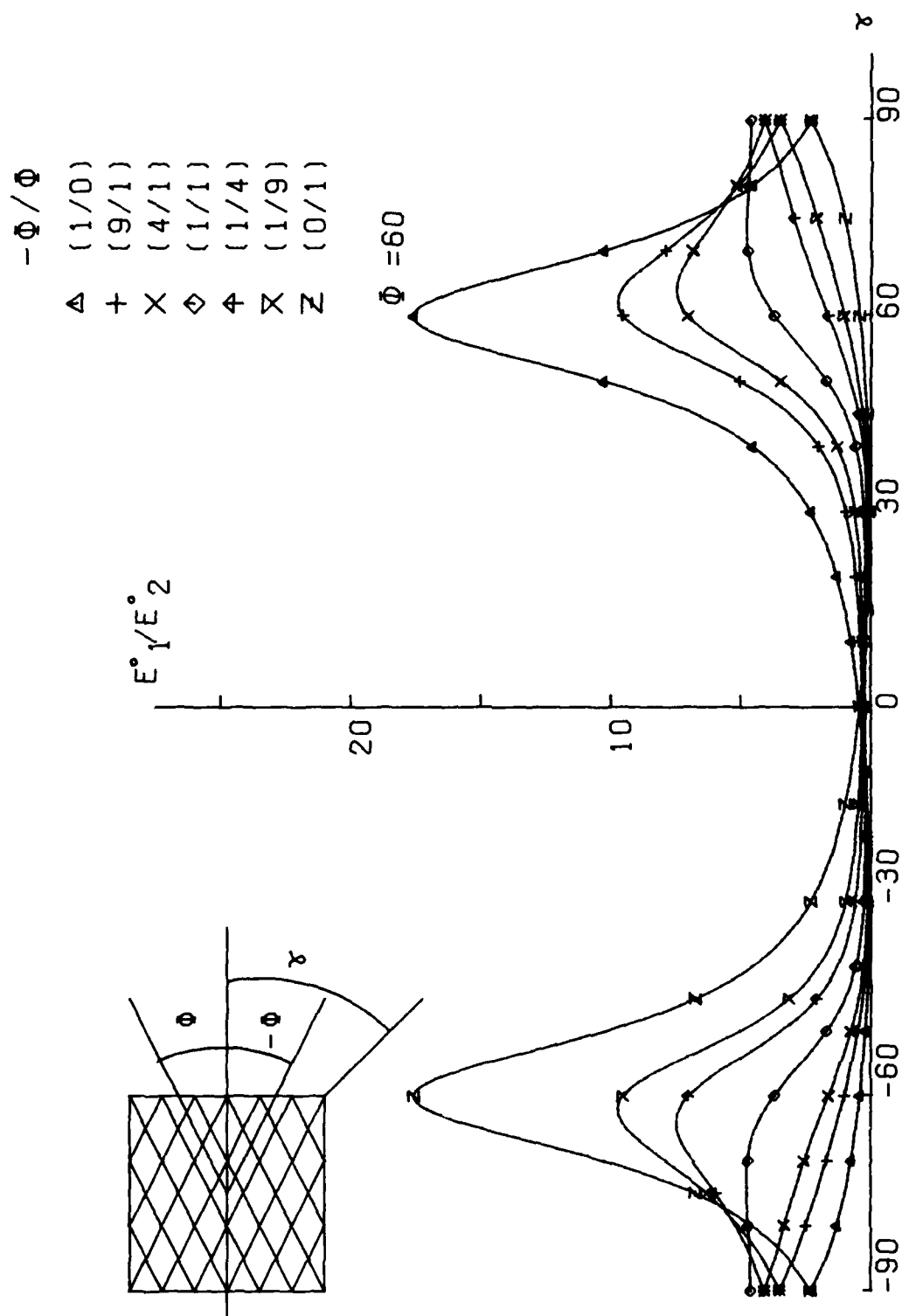


FIG.:351

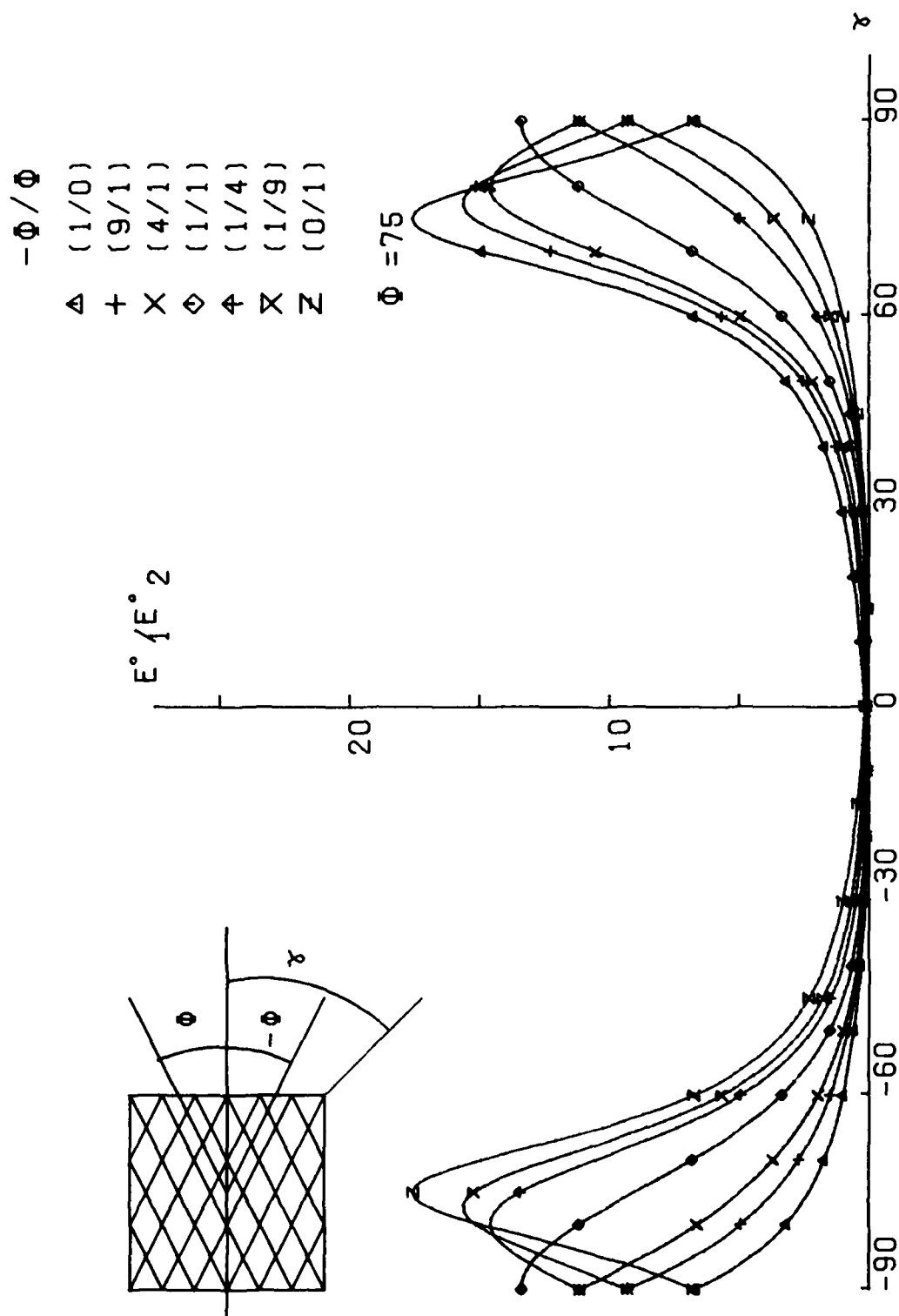


FIG.: 352

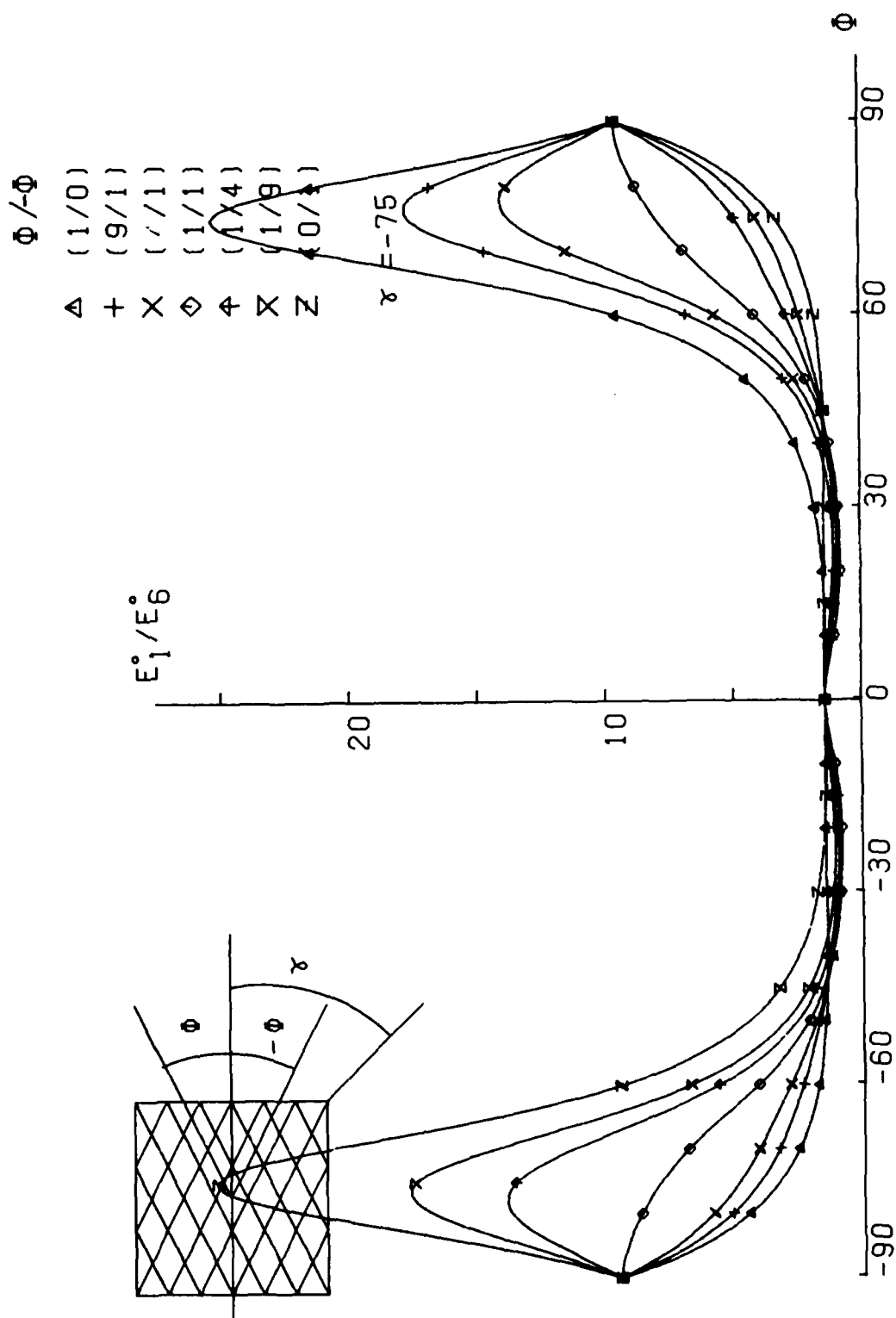


FIG.: 353

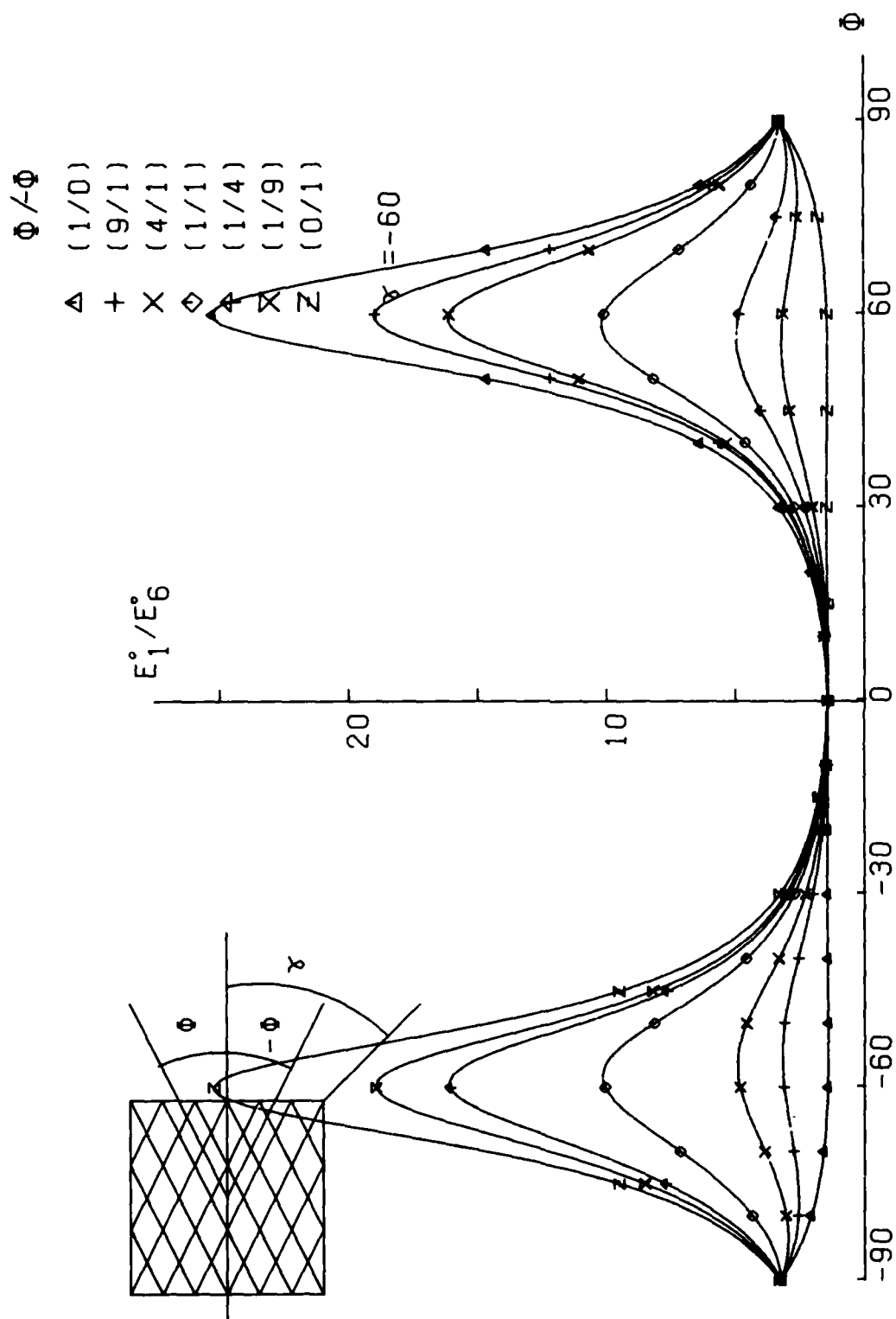


FIG.: 354

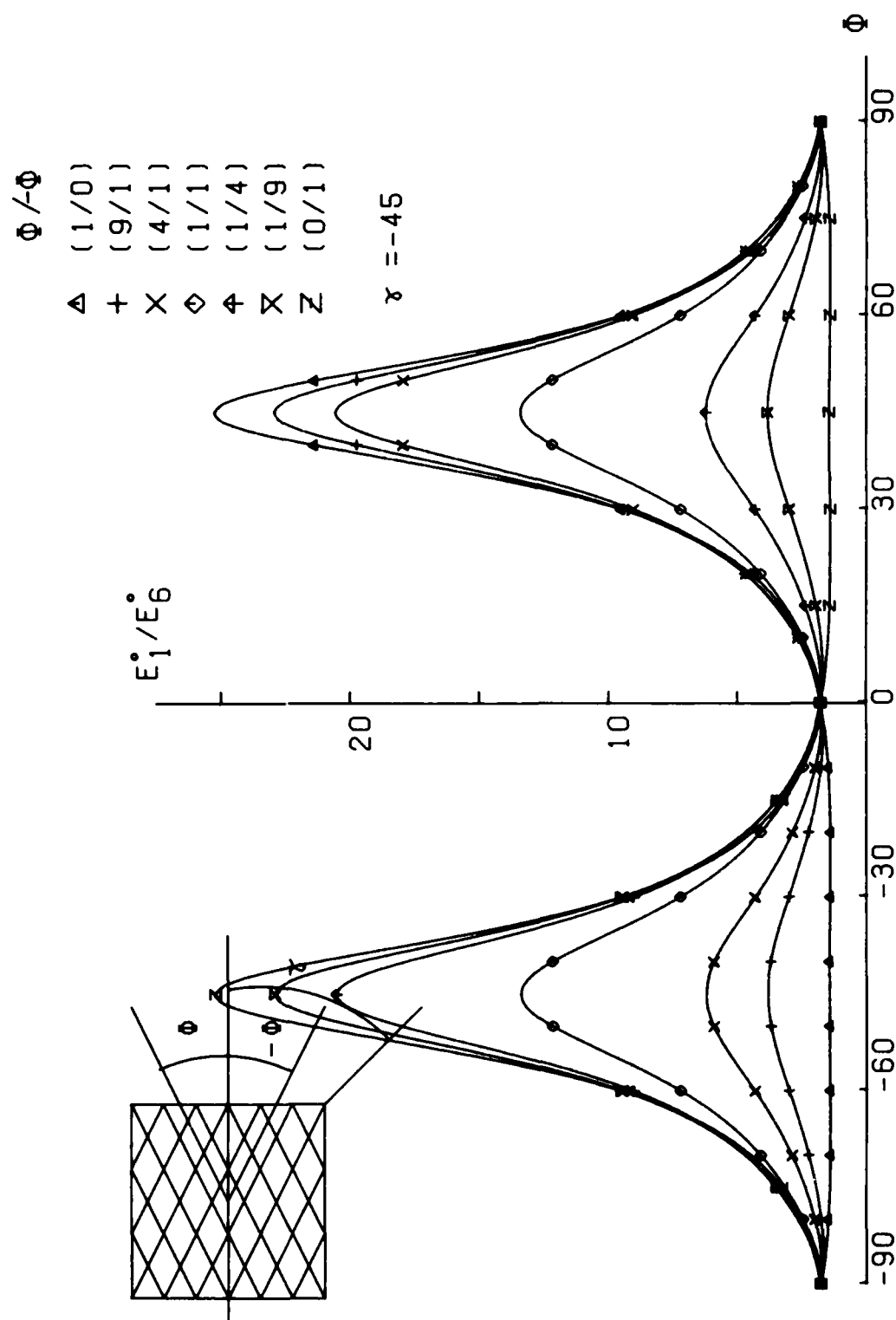


FIG.: 355

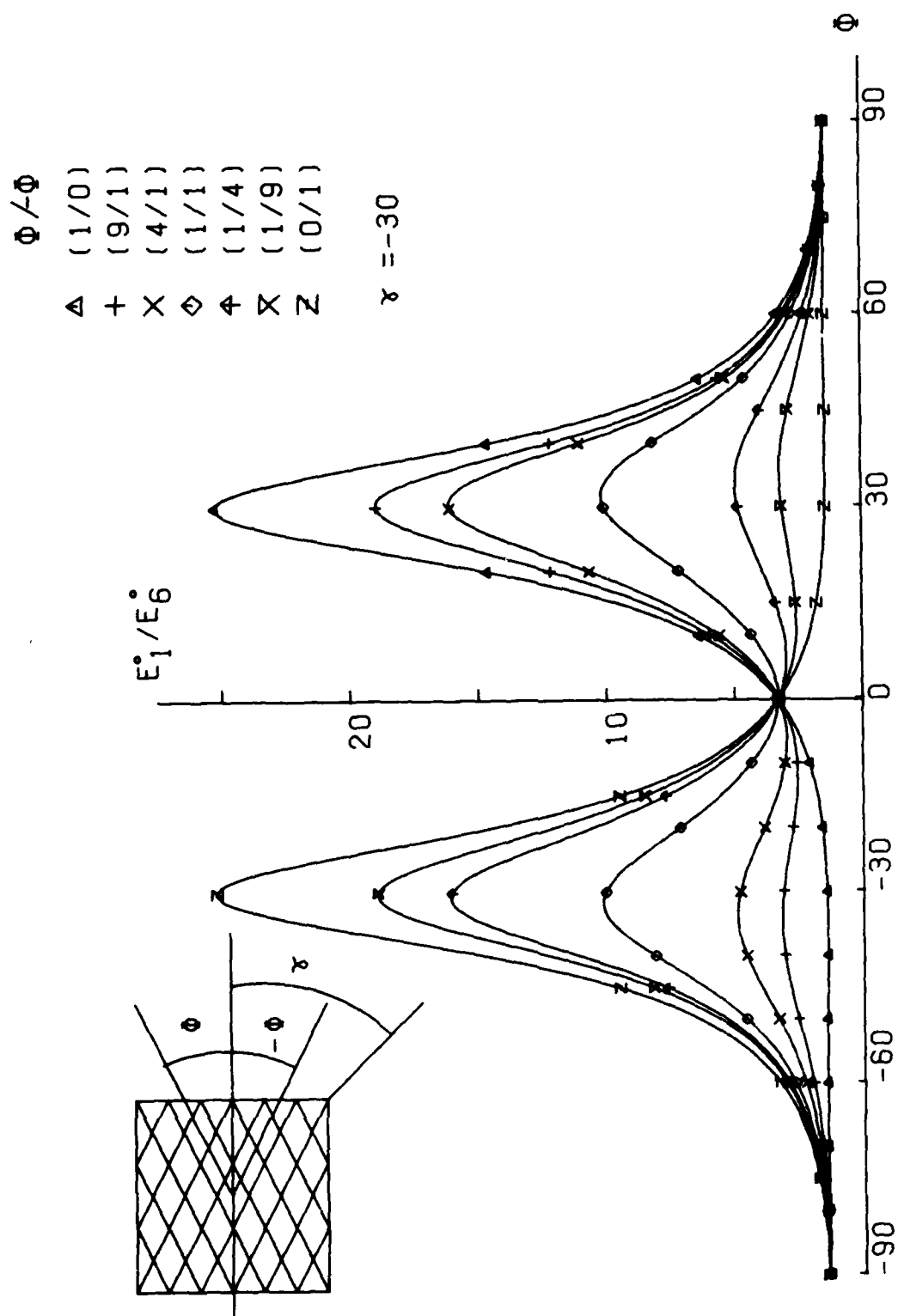


FIG.:356

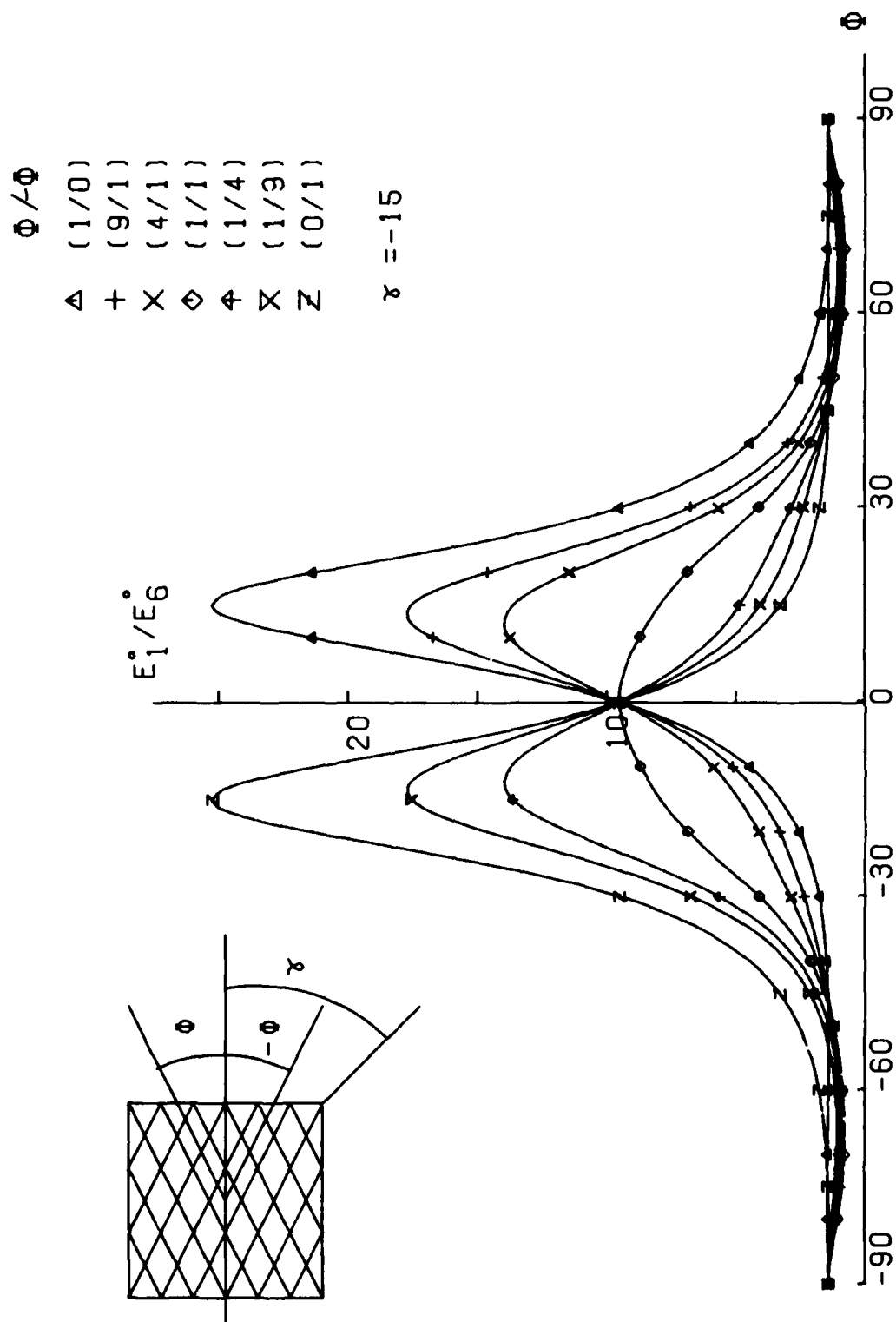


FIG.: 357

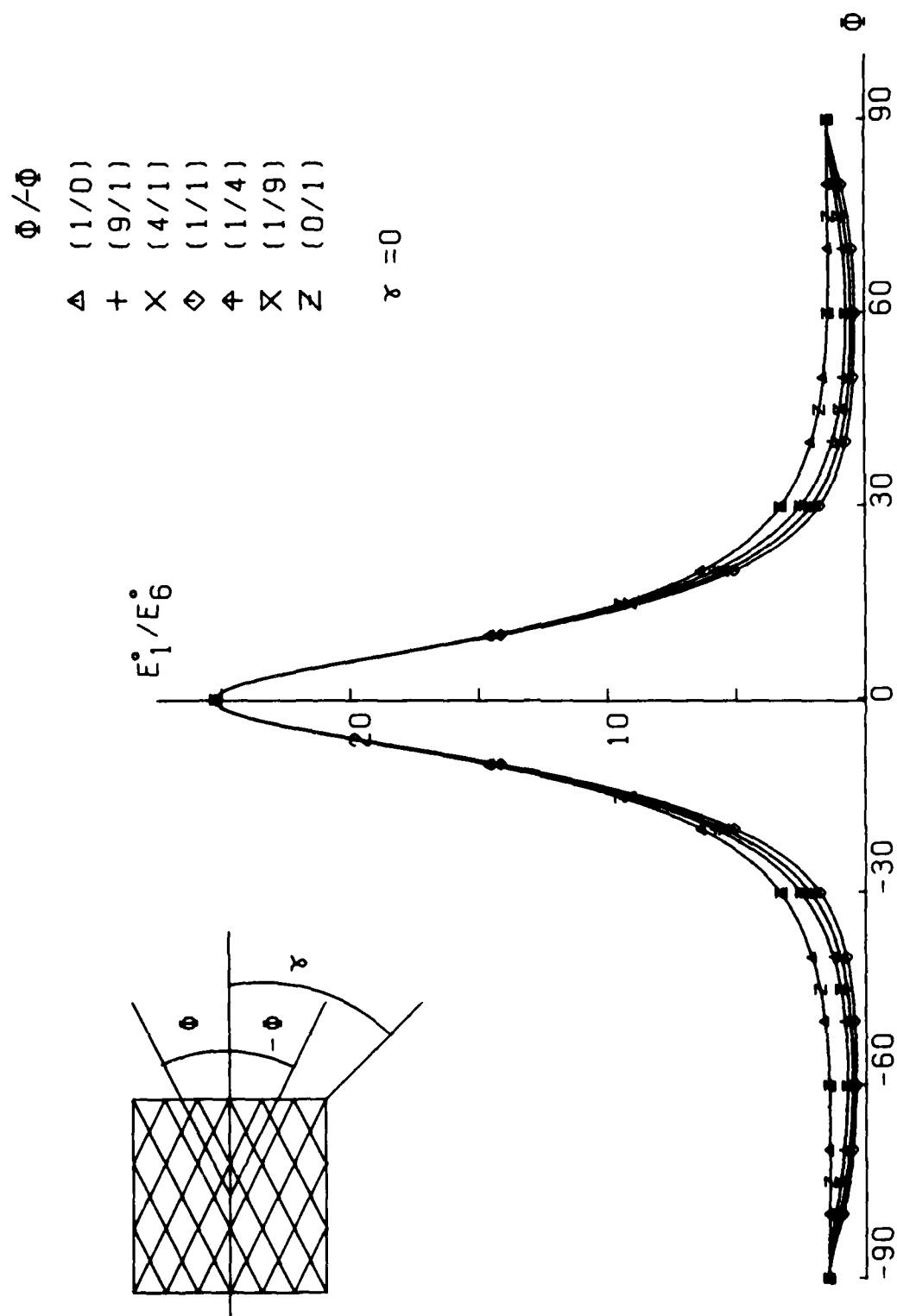


FIG.: 358

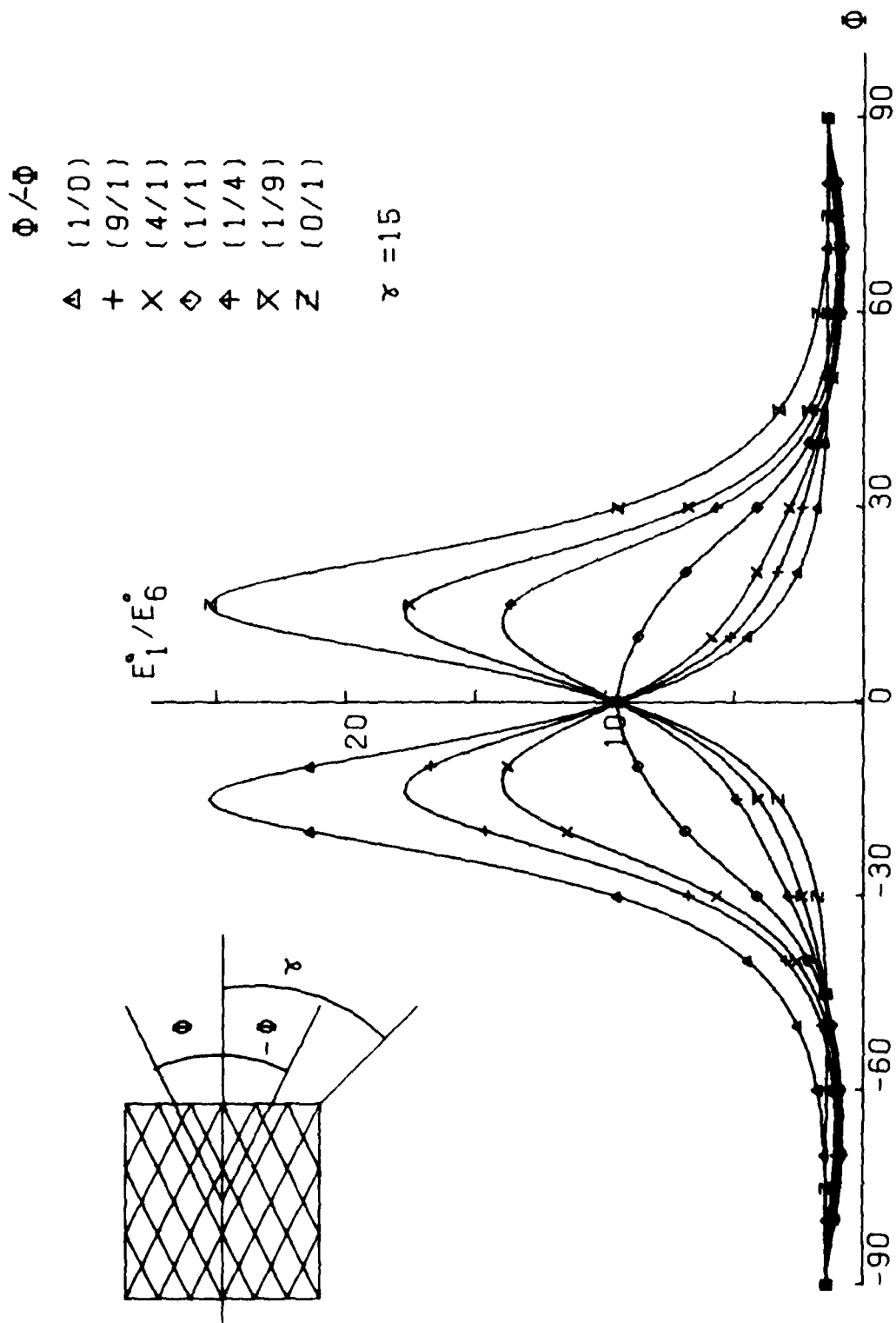


FIG.: 359

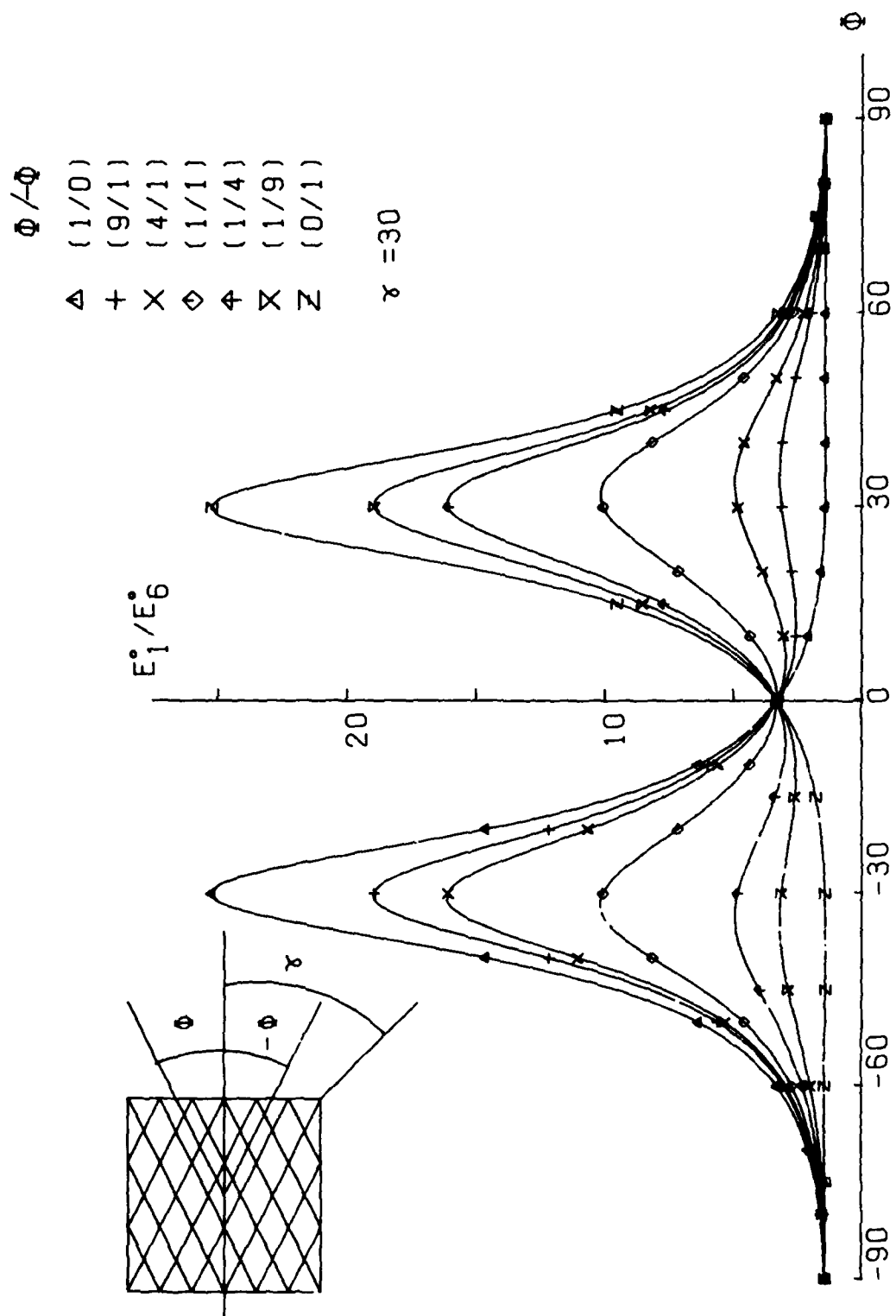


FIG.: 360

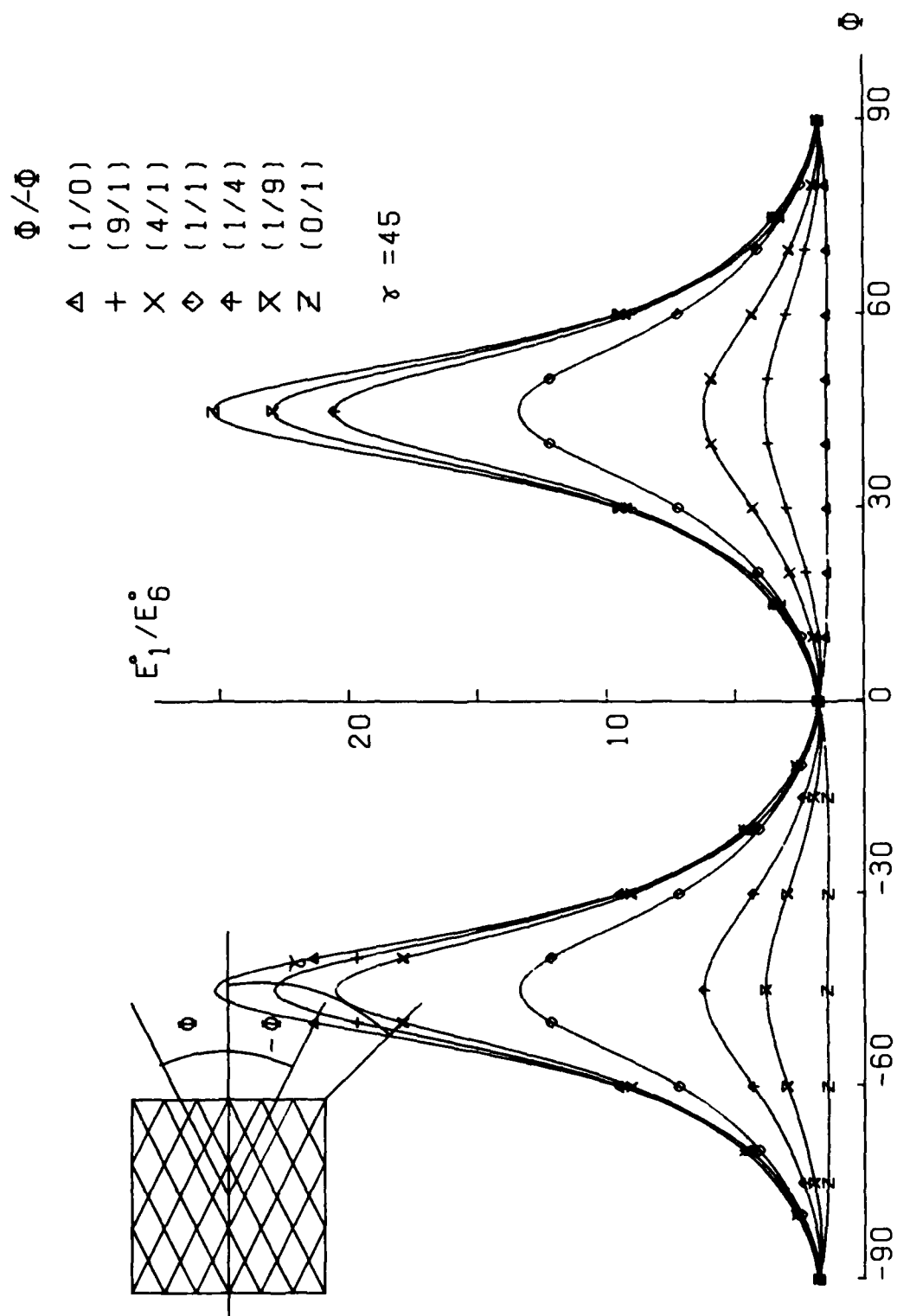


FIG.: 361

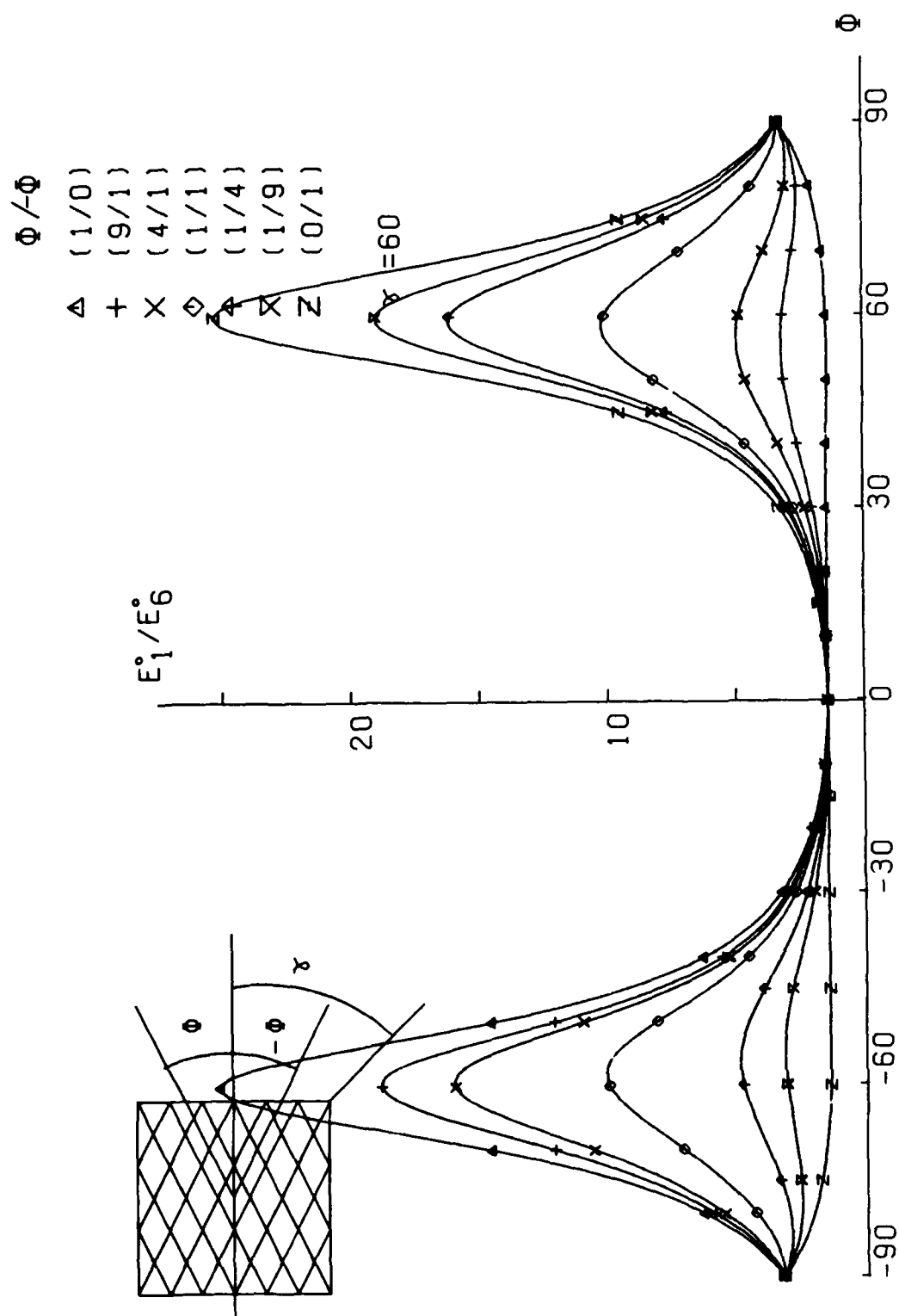


FIG.:362

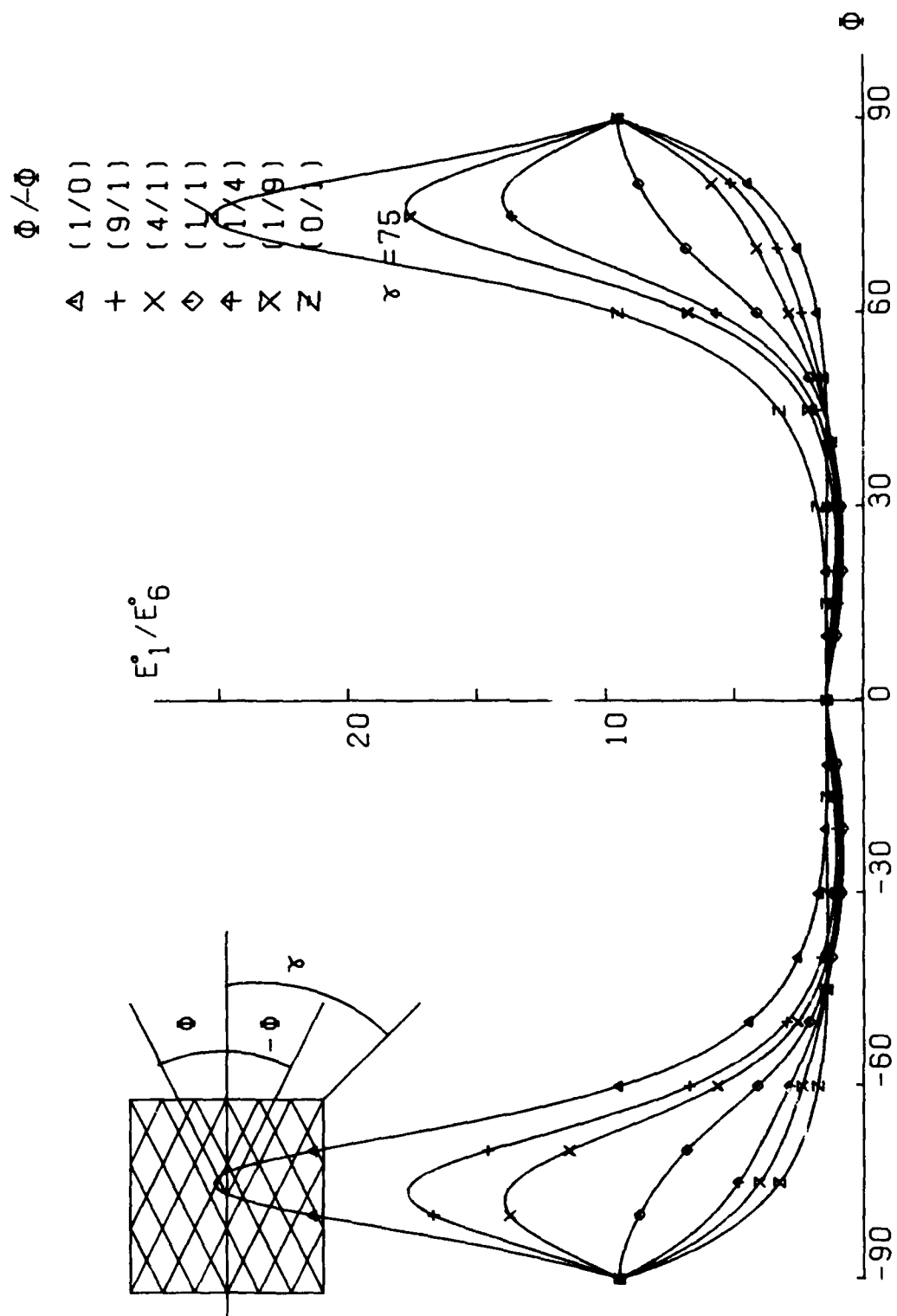


FIG.: 363

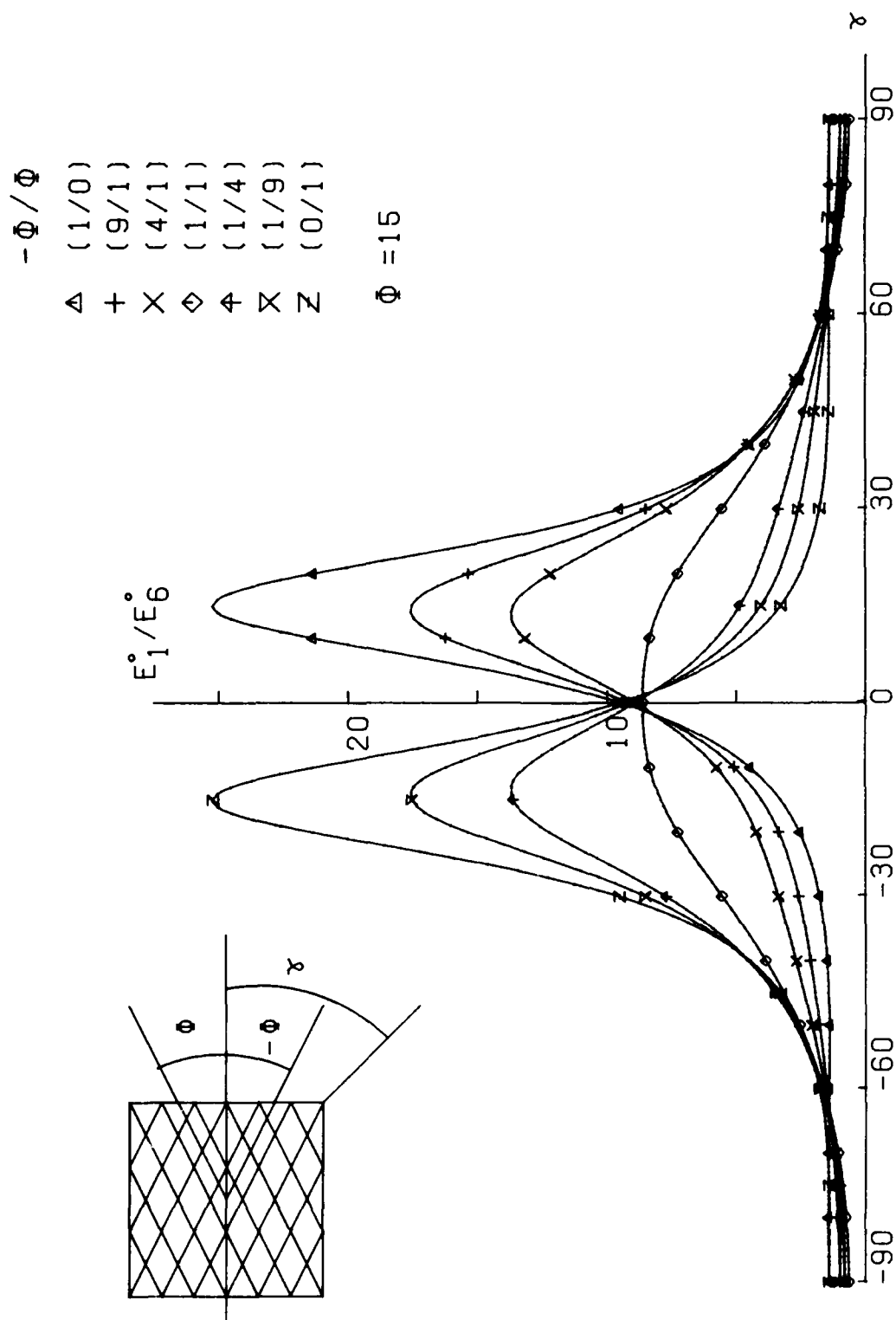


FIG.: 364

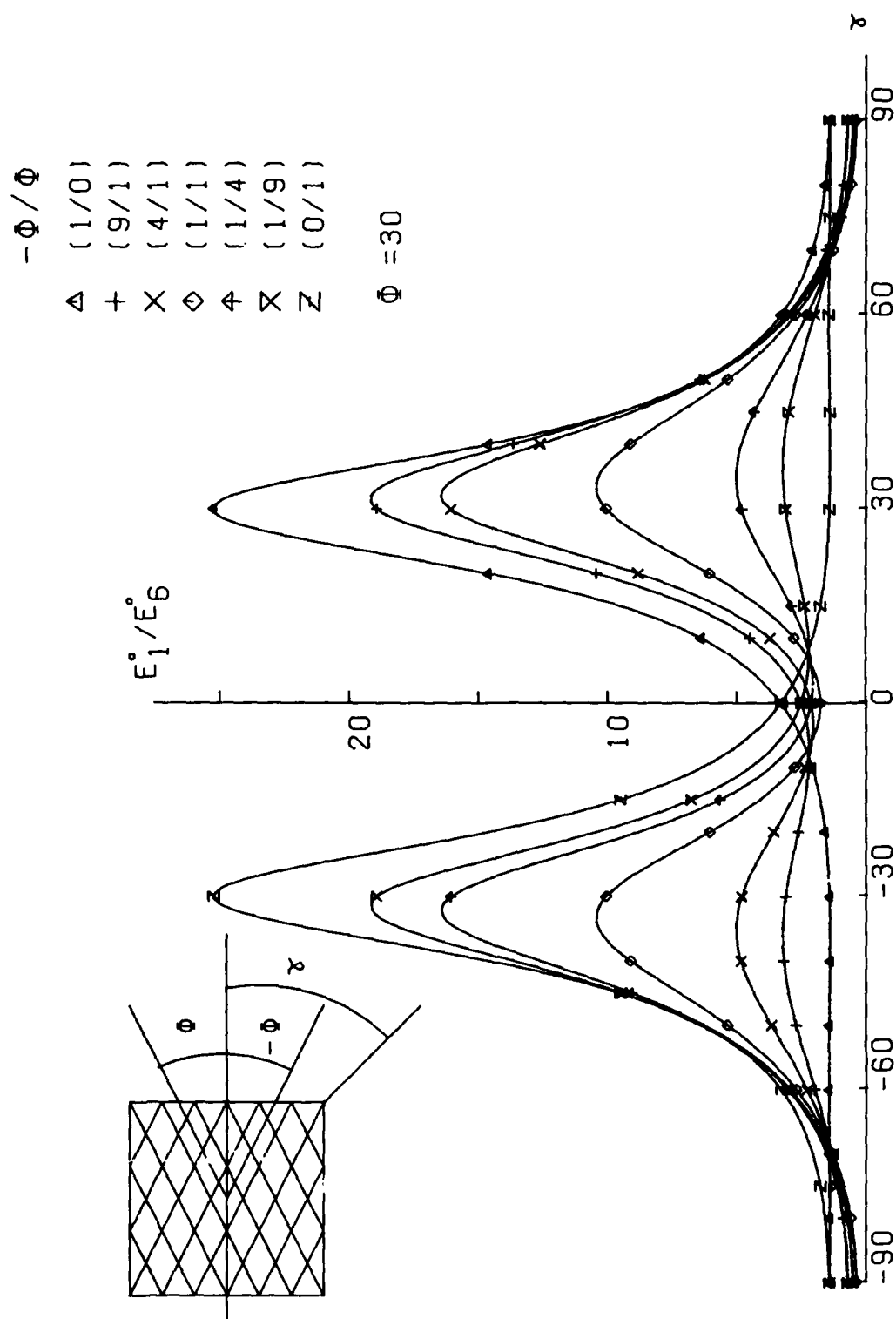


FIG.: 365

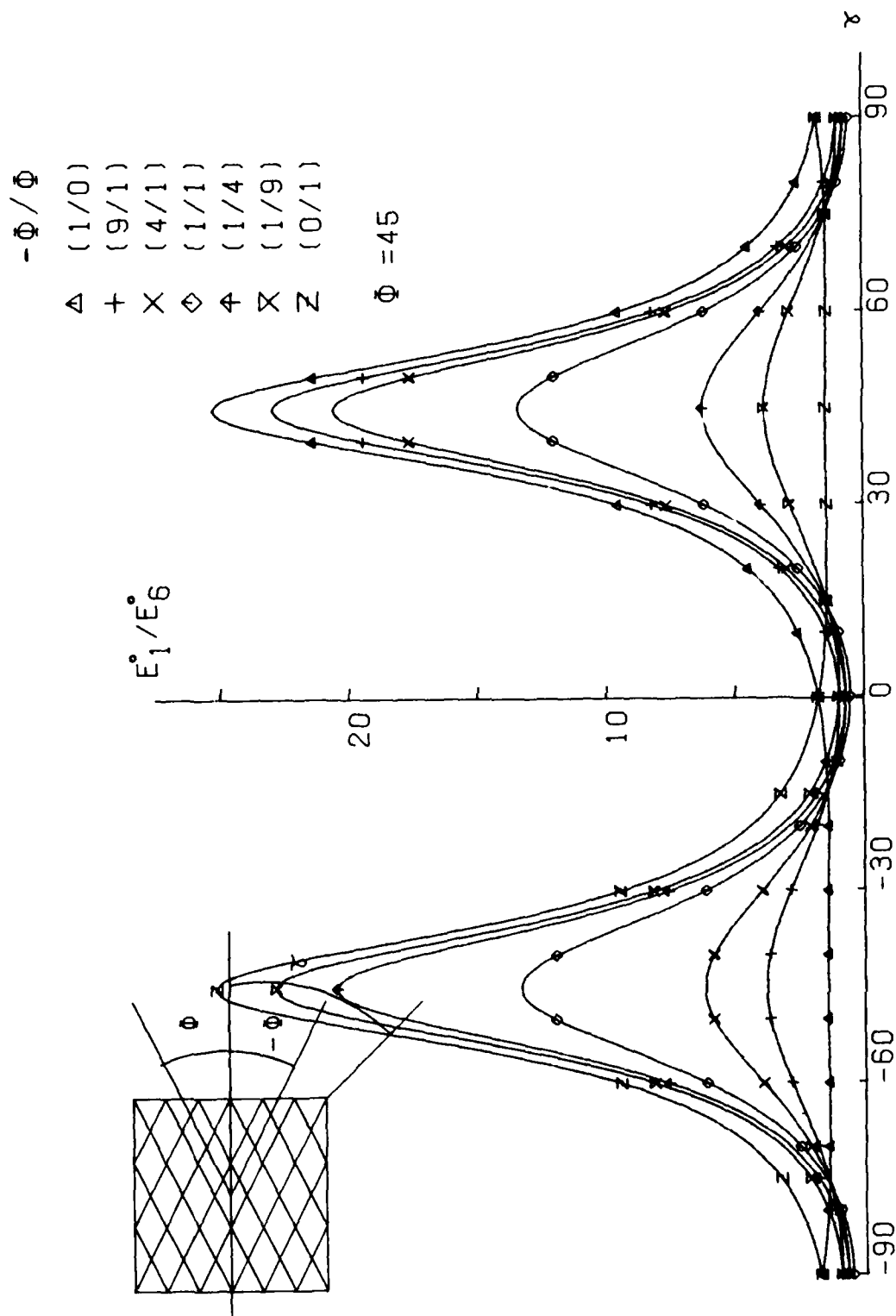


FIG.: 366

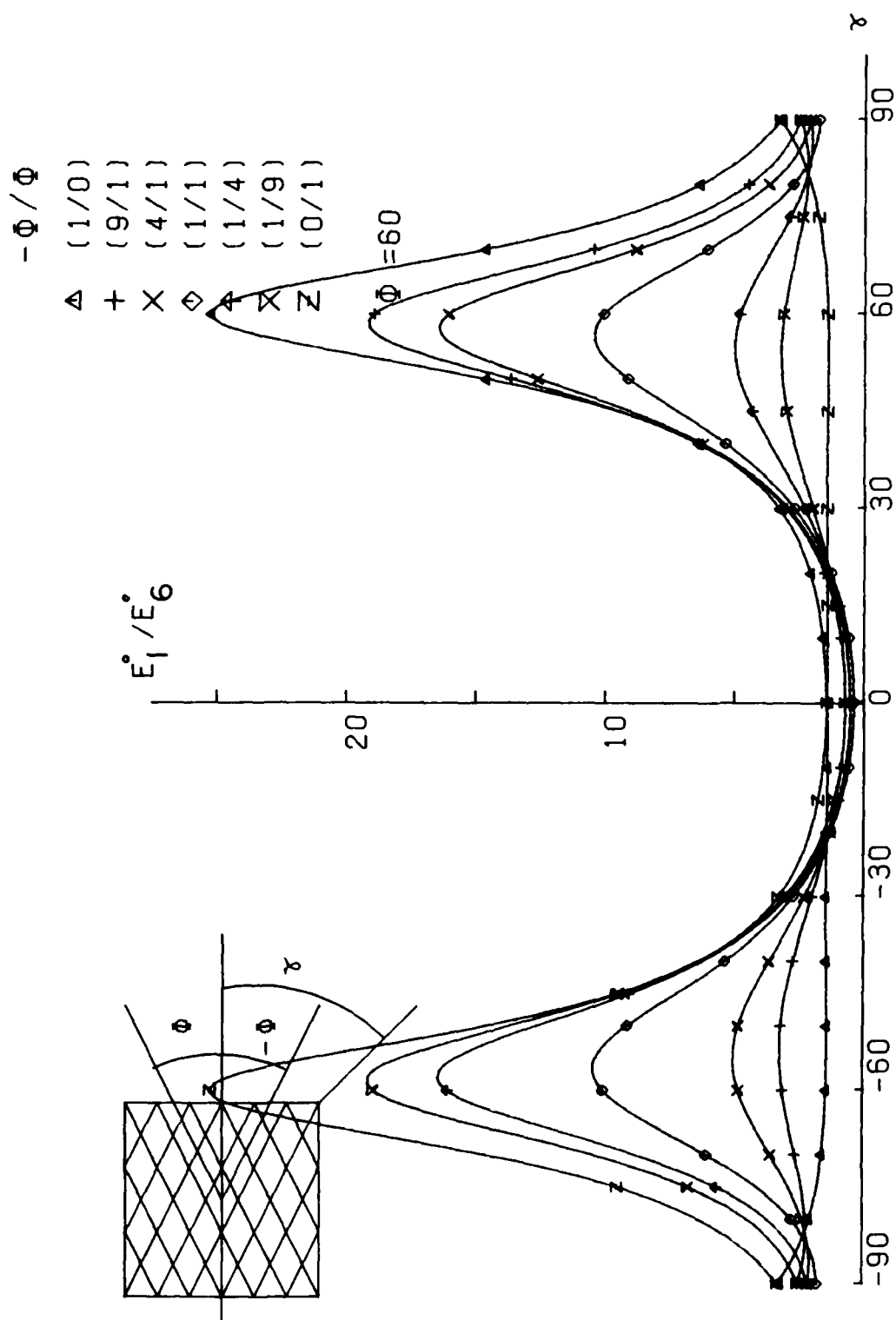


FIG.:367

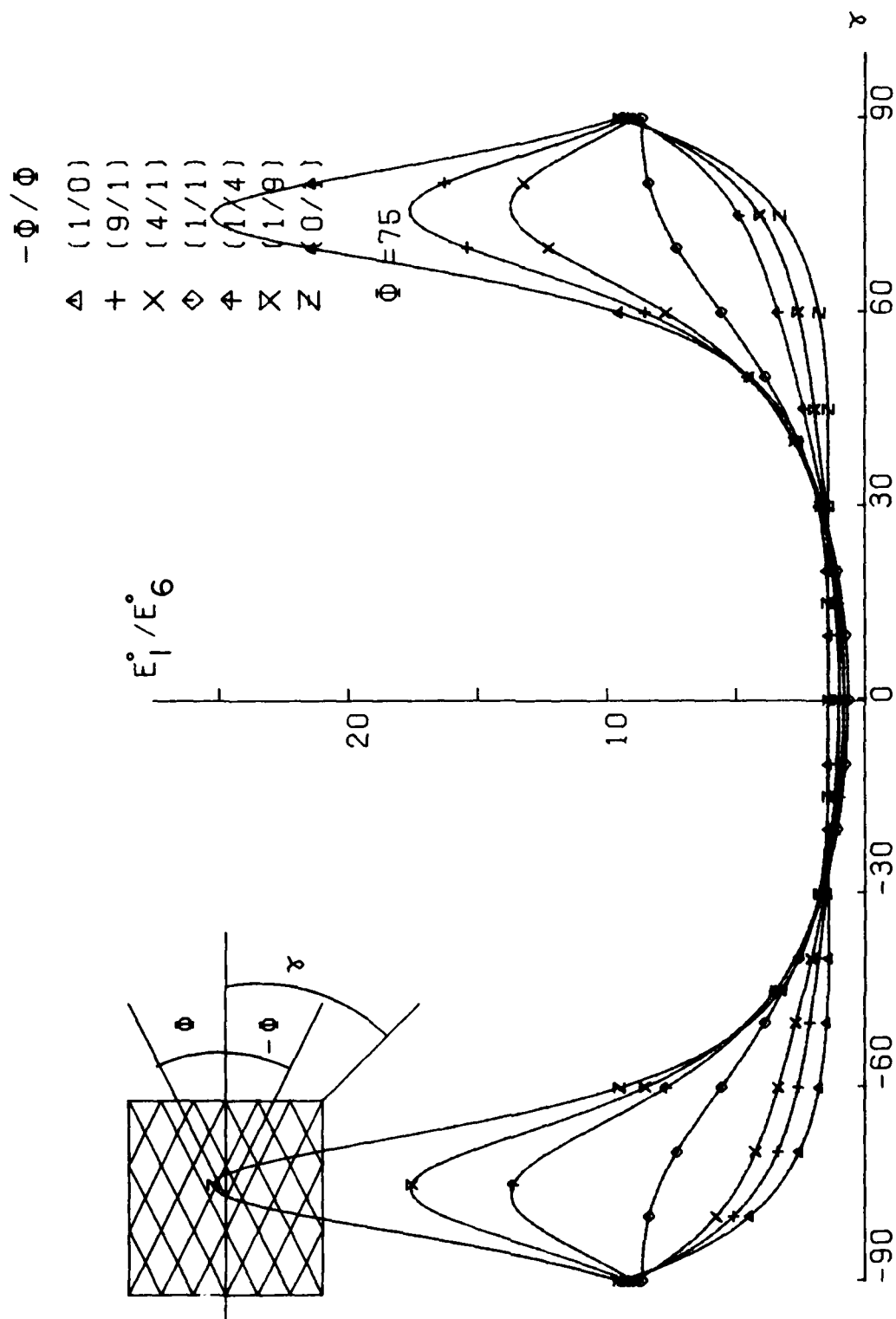


FIG.: 368

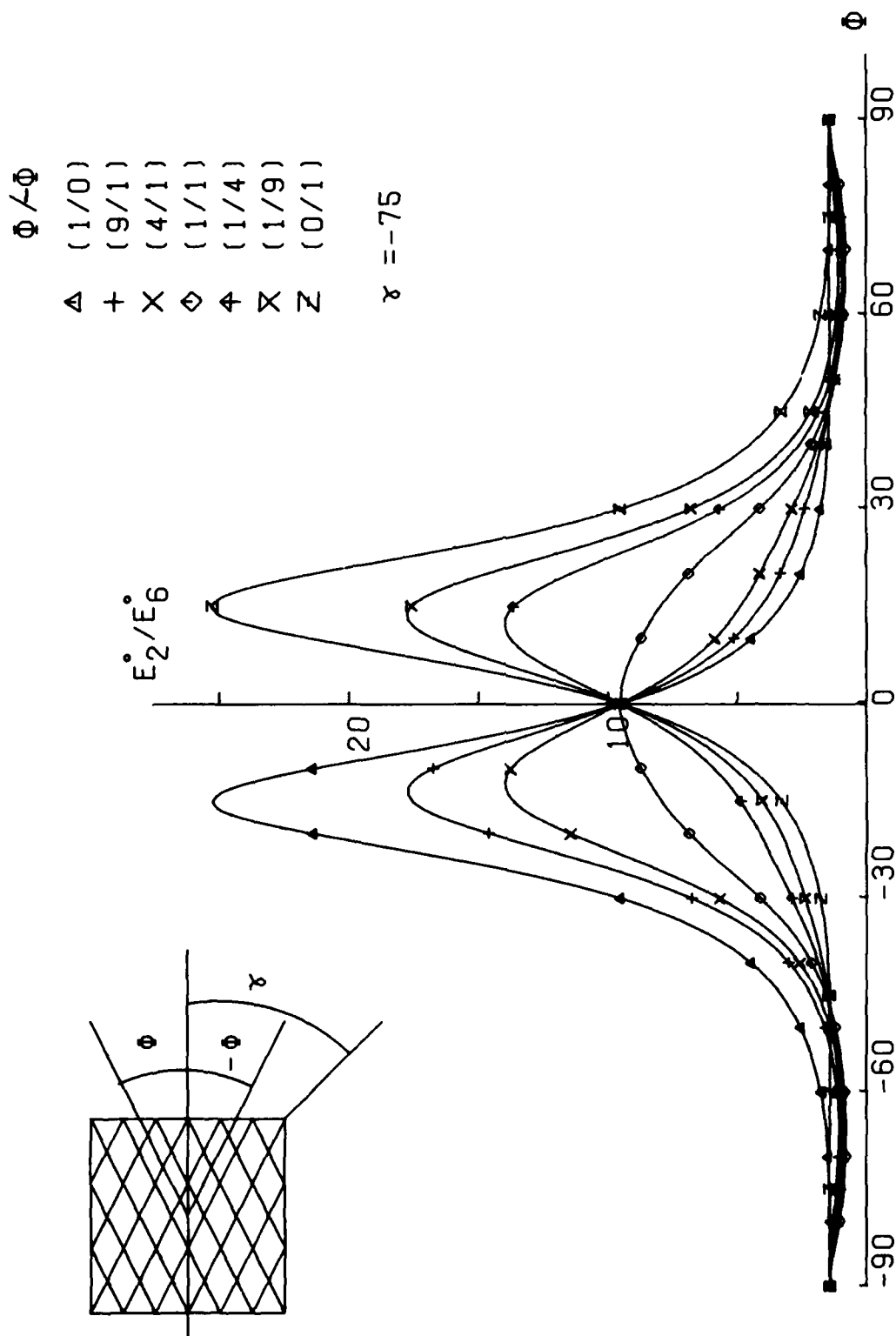


FIG.: 369

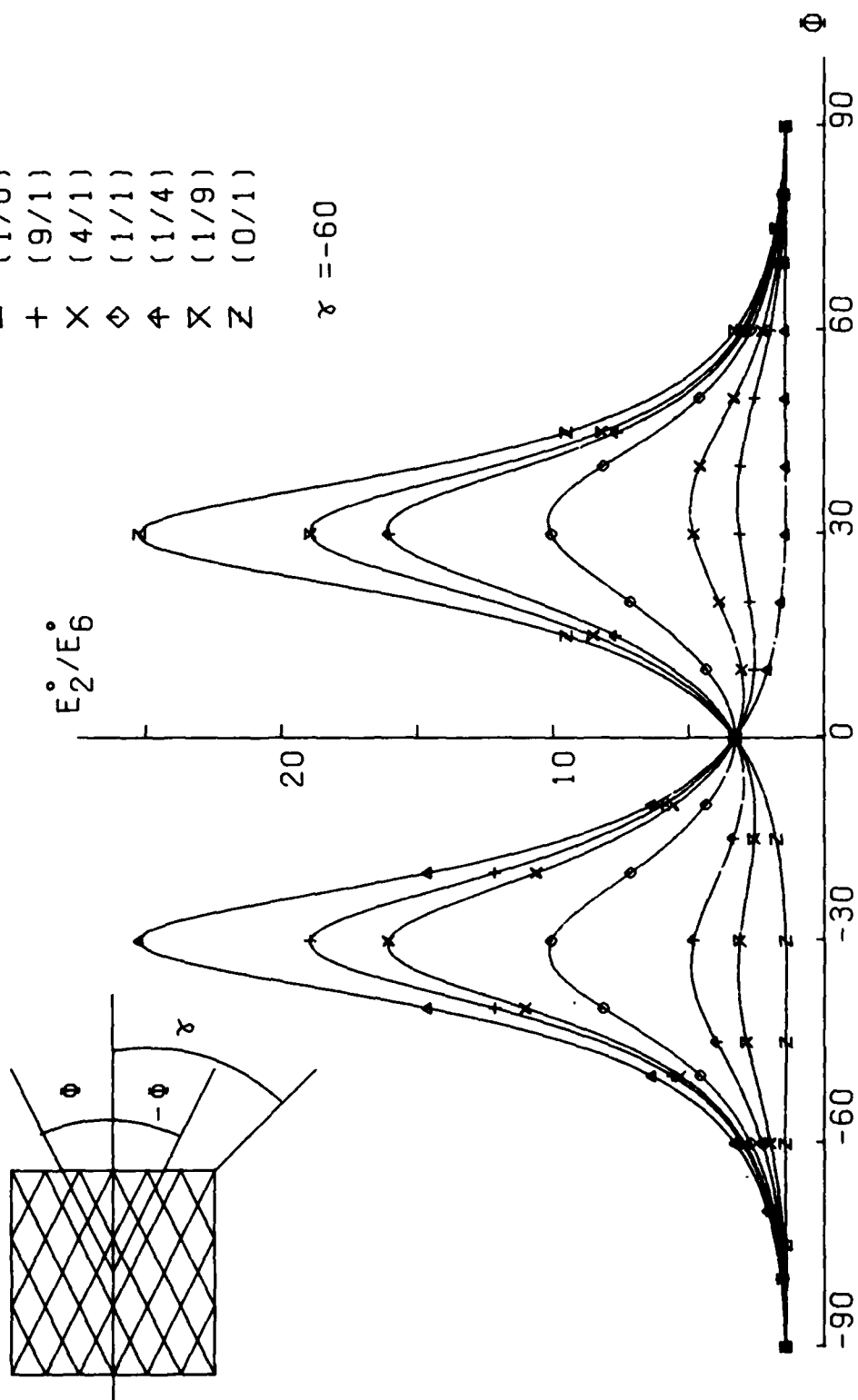


FIG.: 370

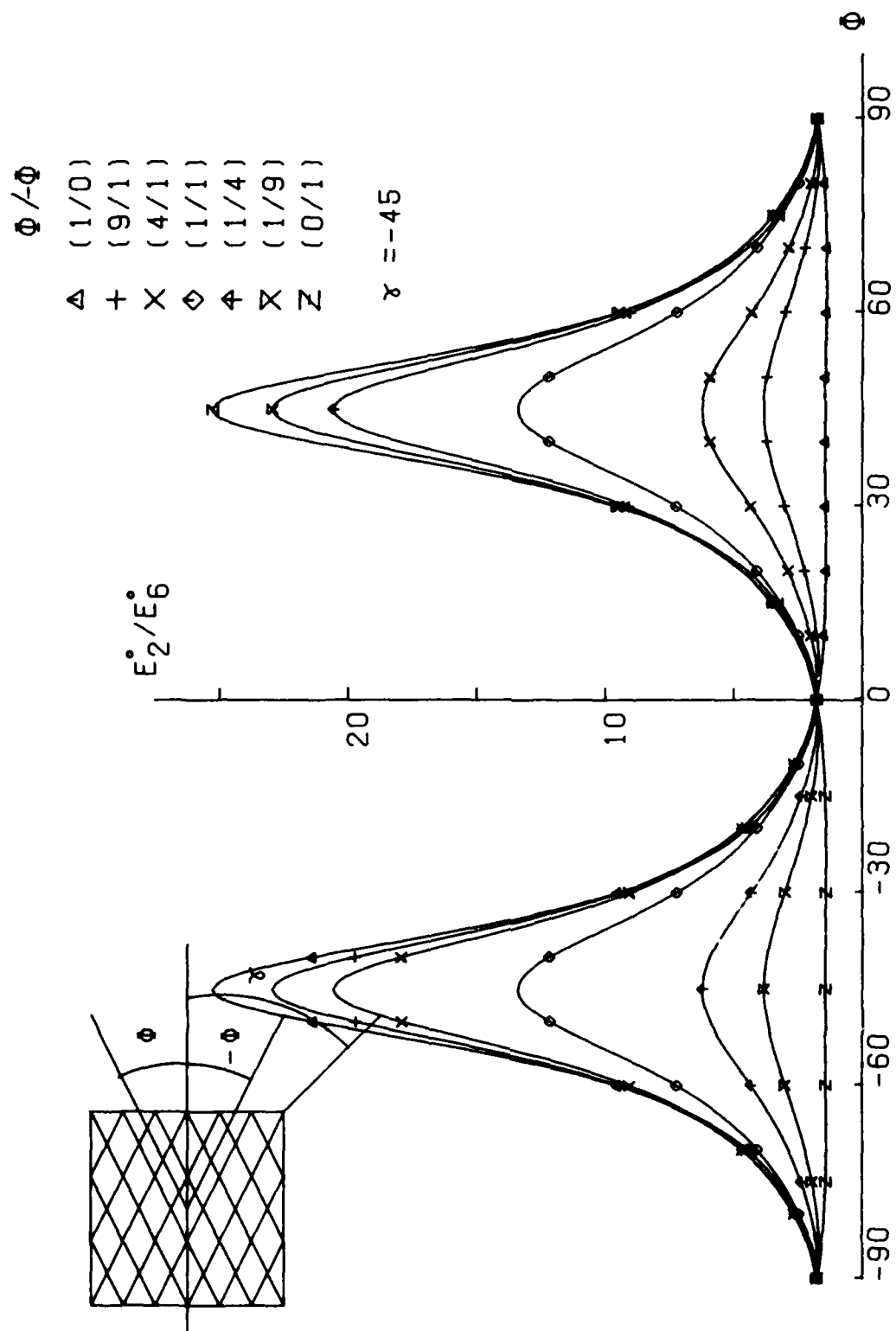


FIG.: 371

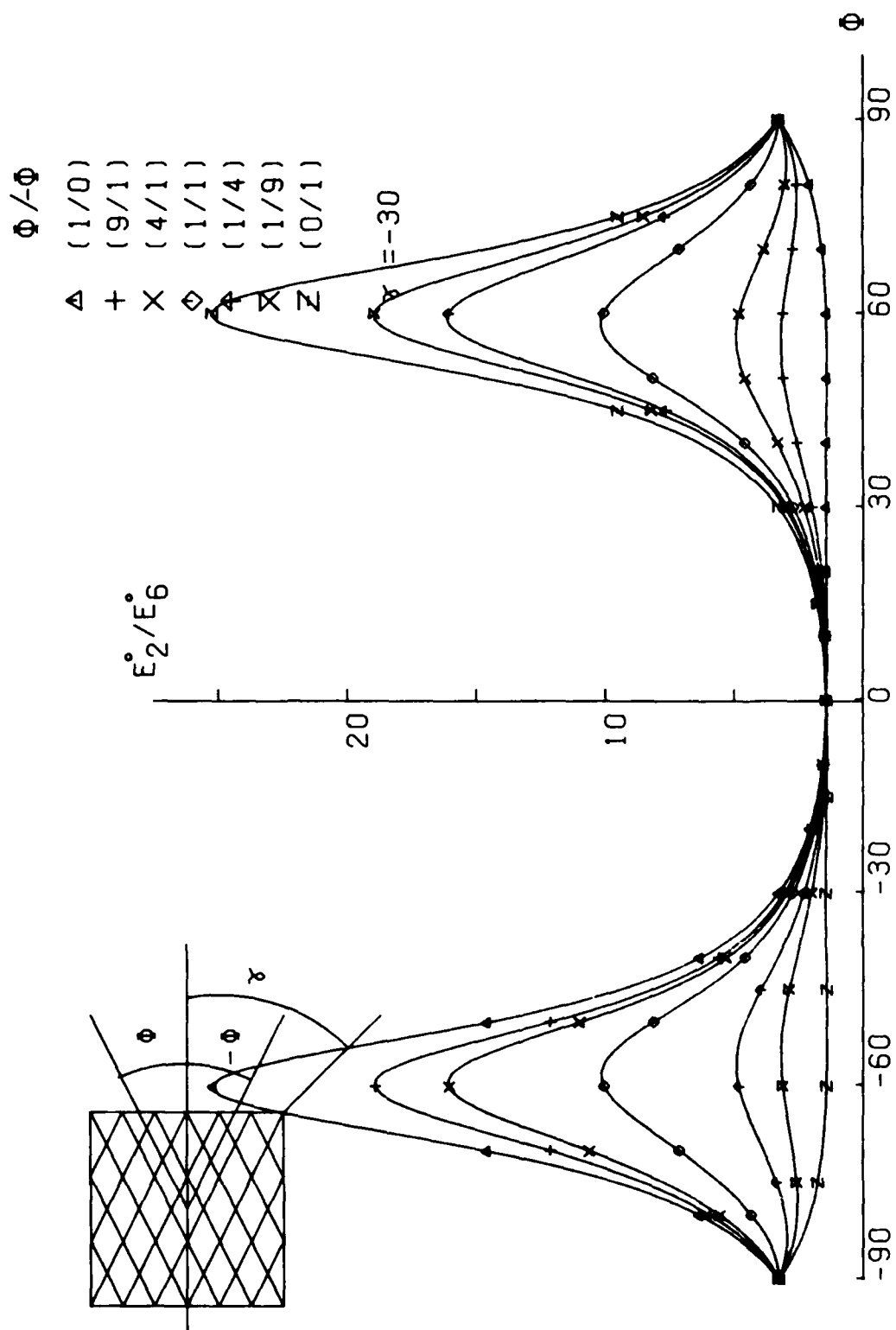


FIG.:372

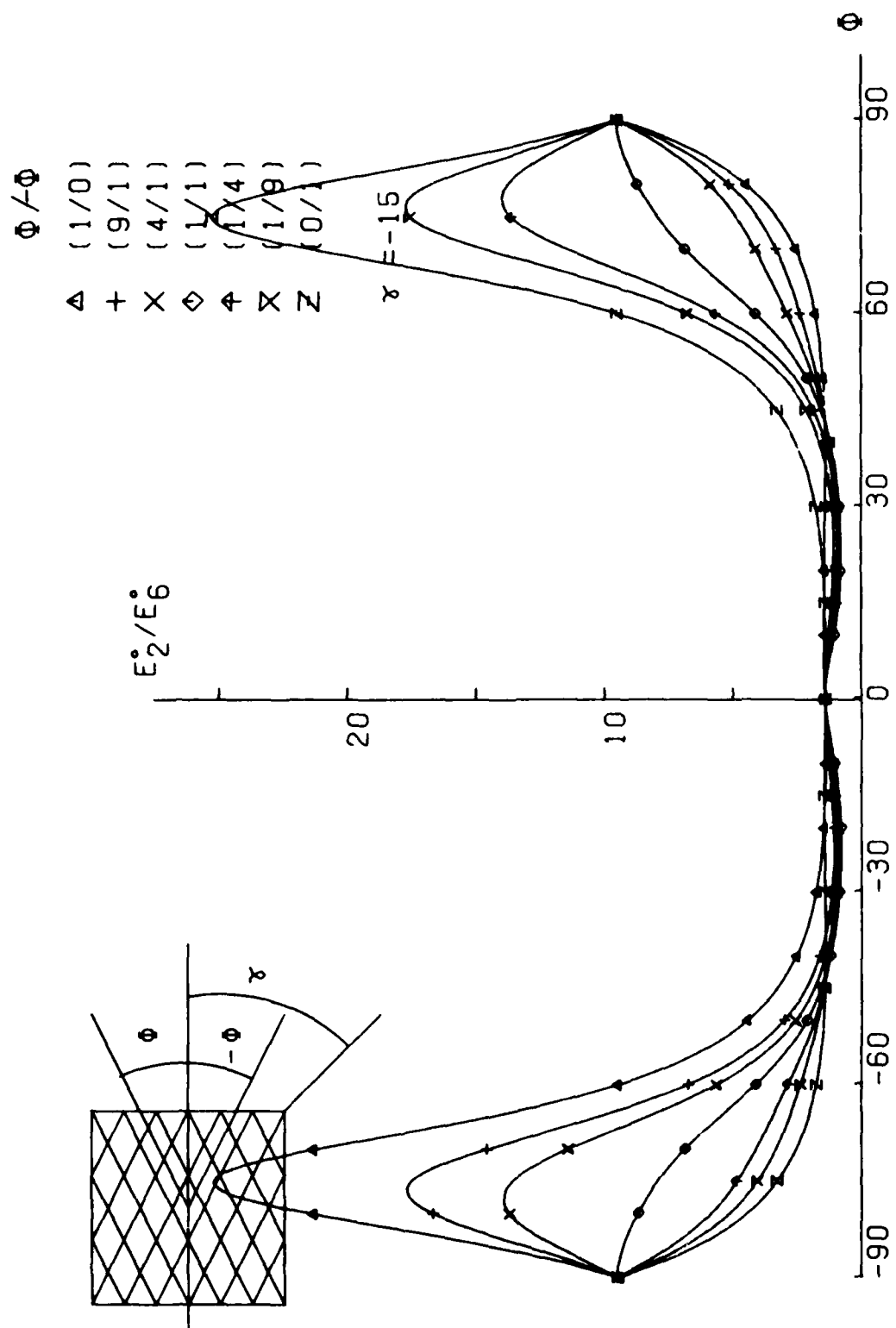


FIG.: 373

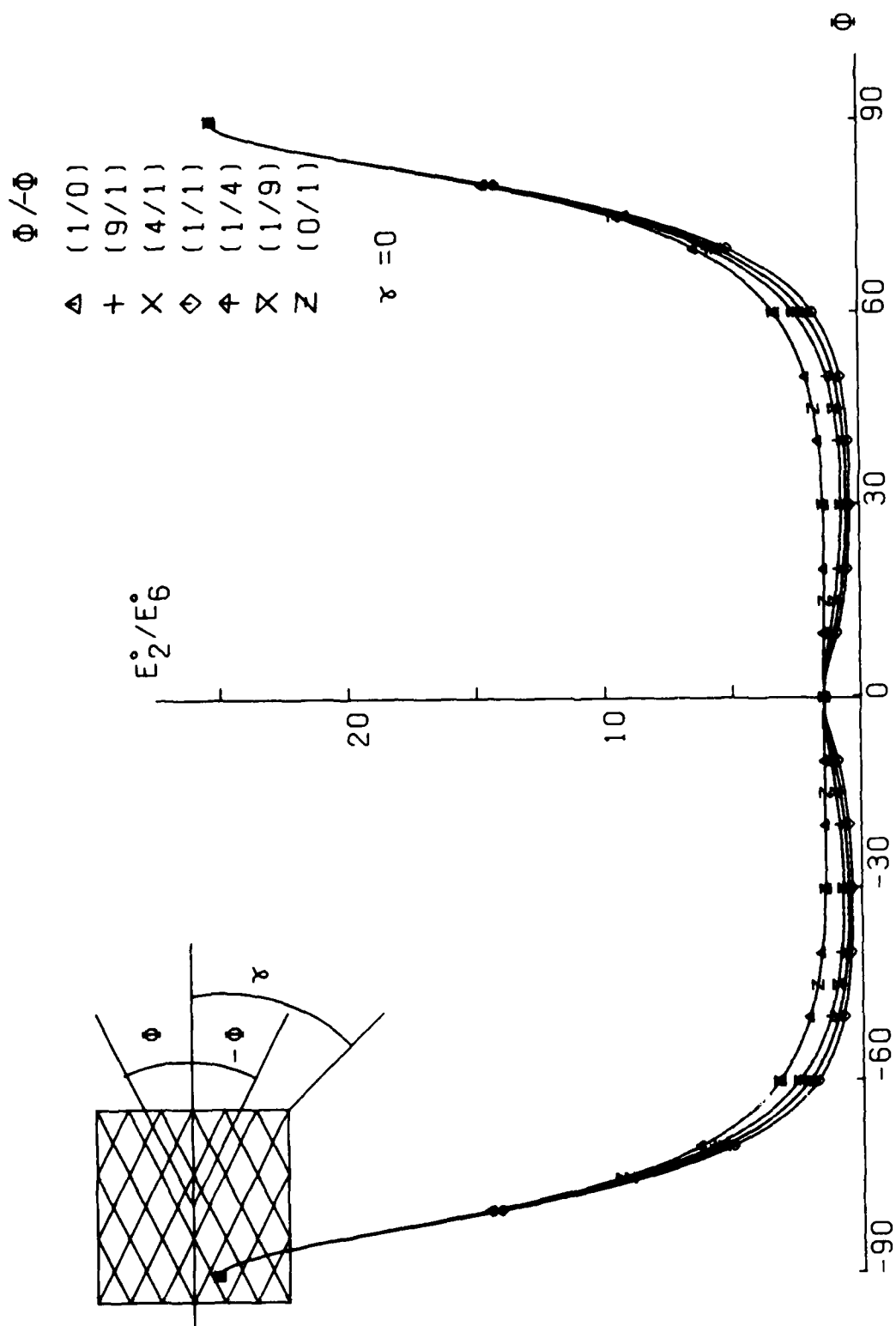


FIG.: 374

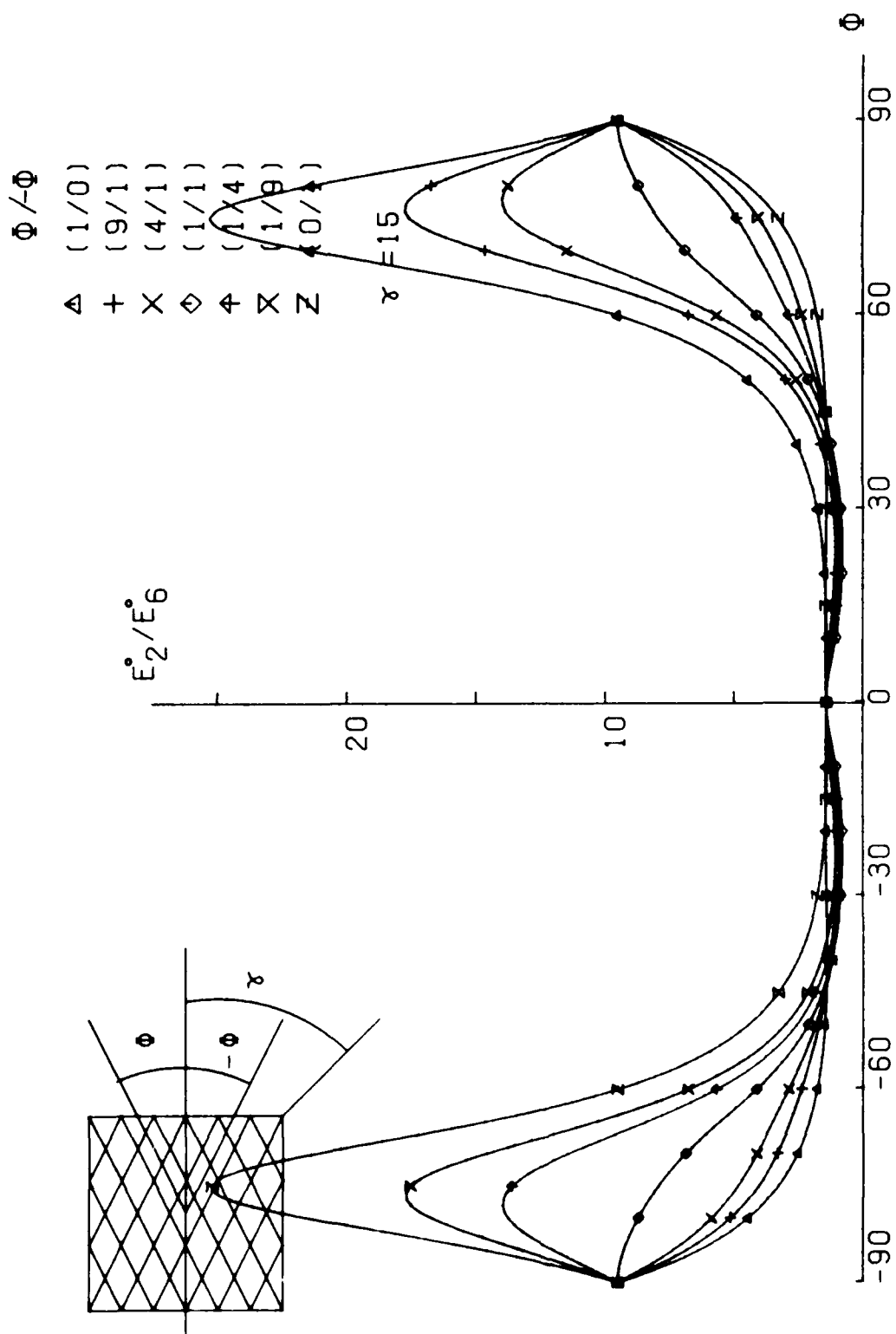
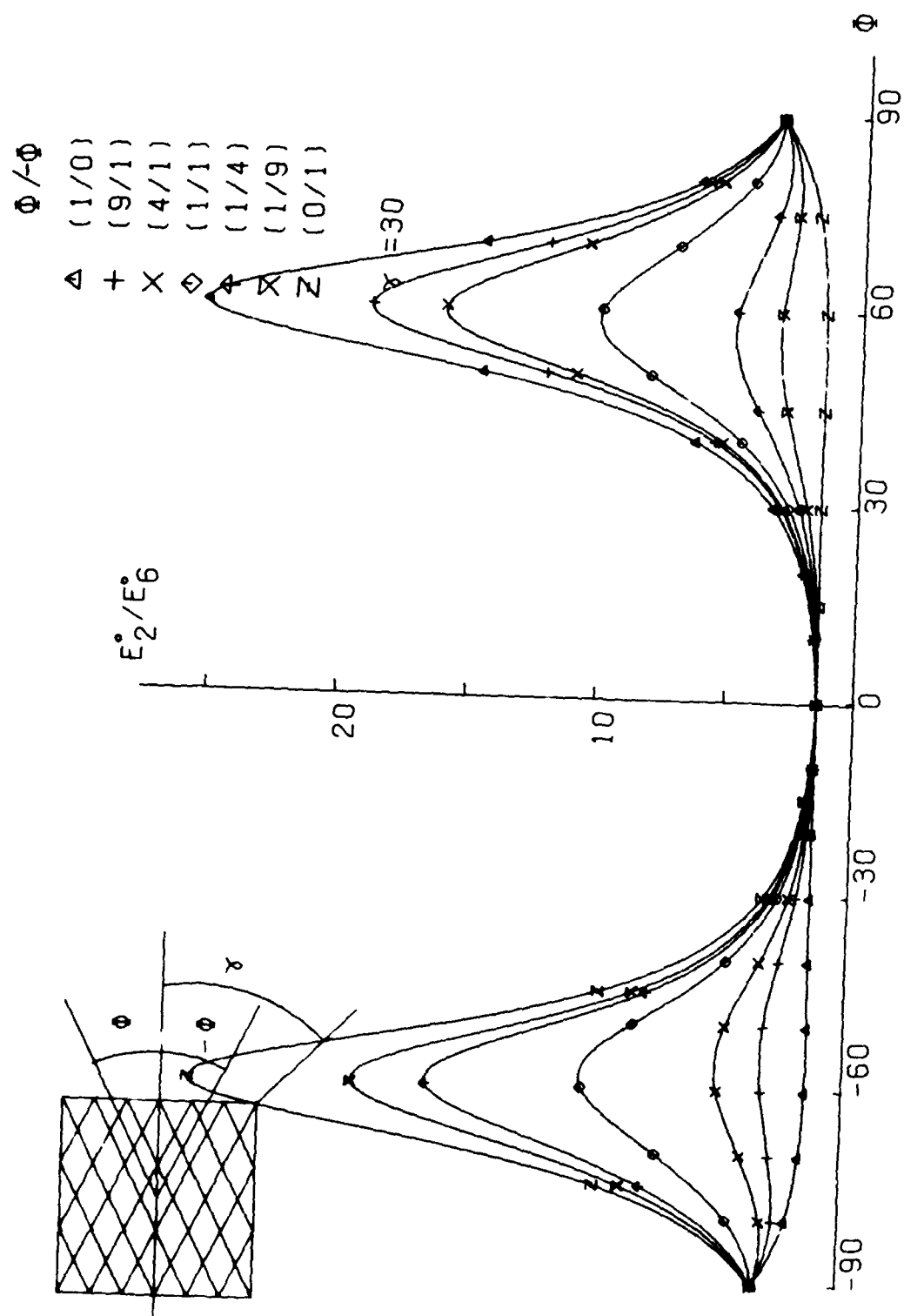


FIG.: 375



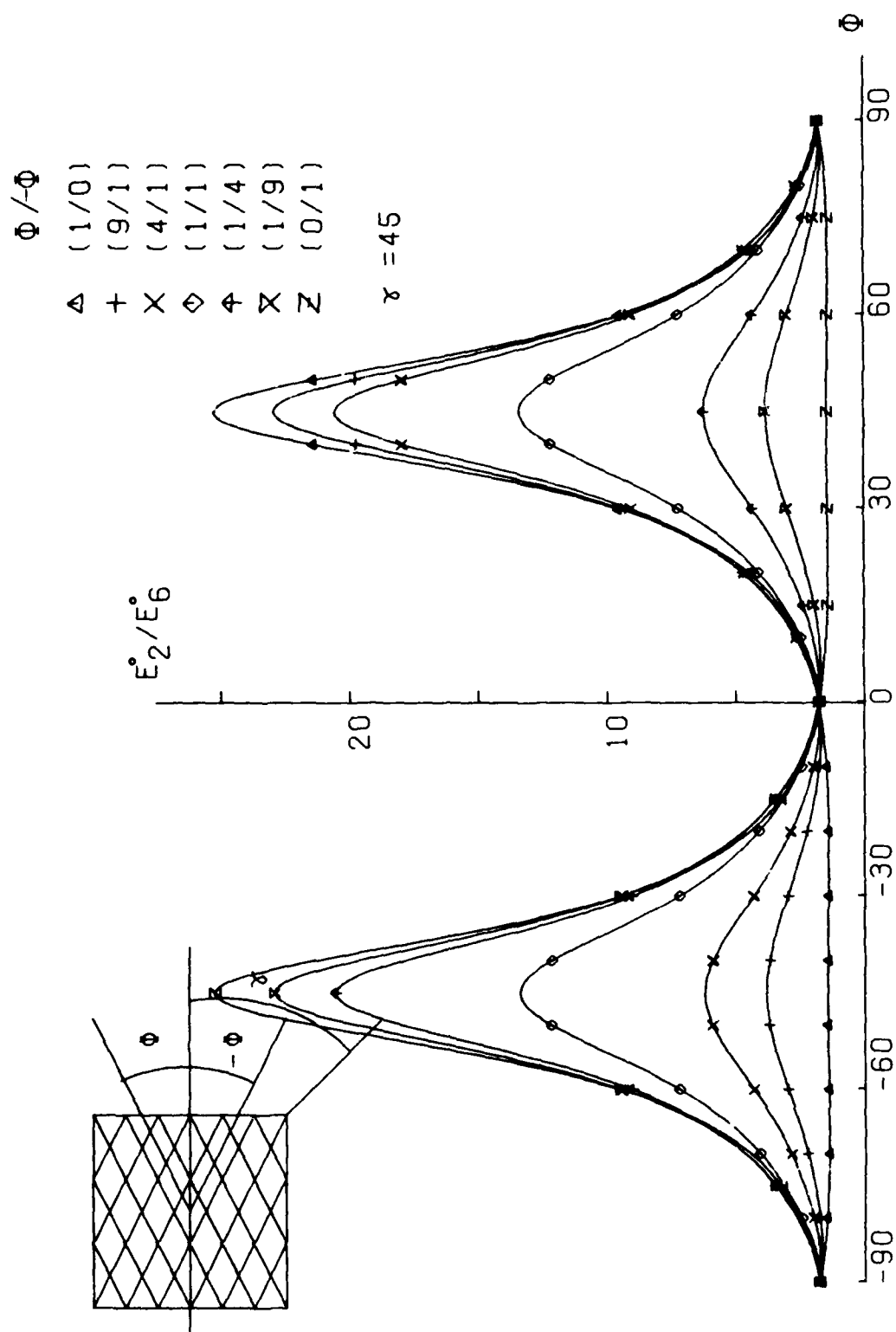


FIG.: 377

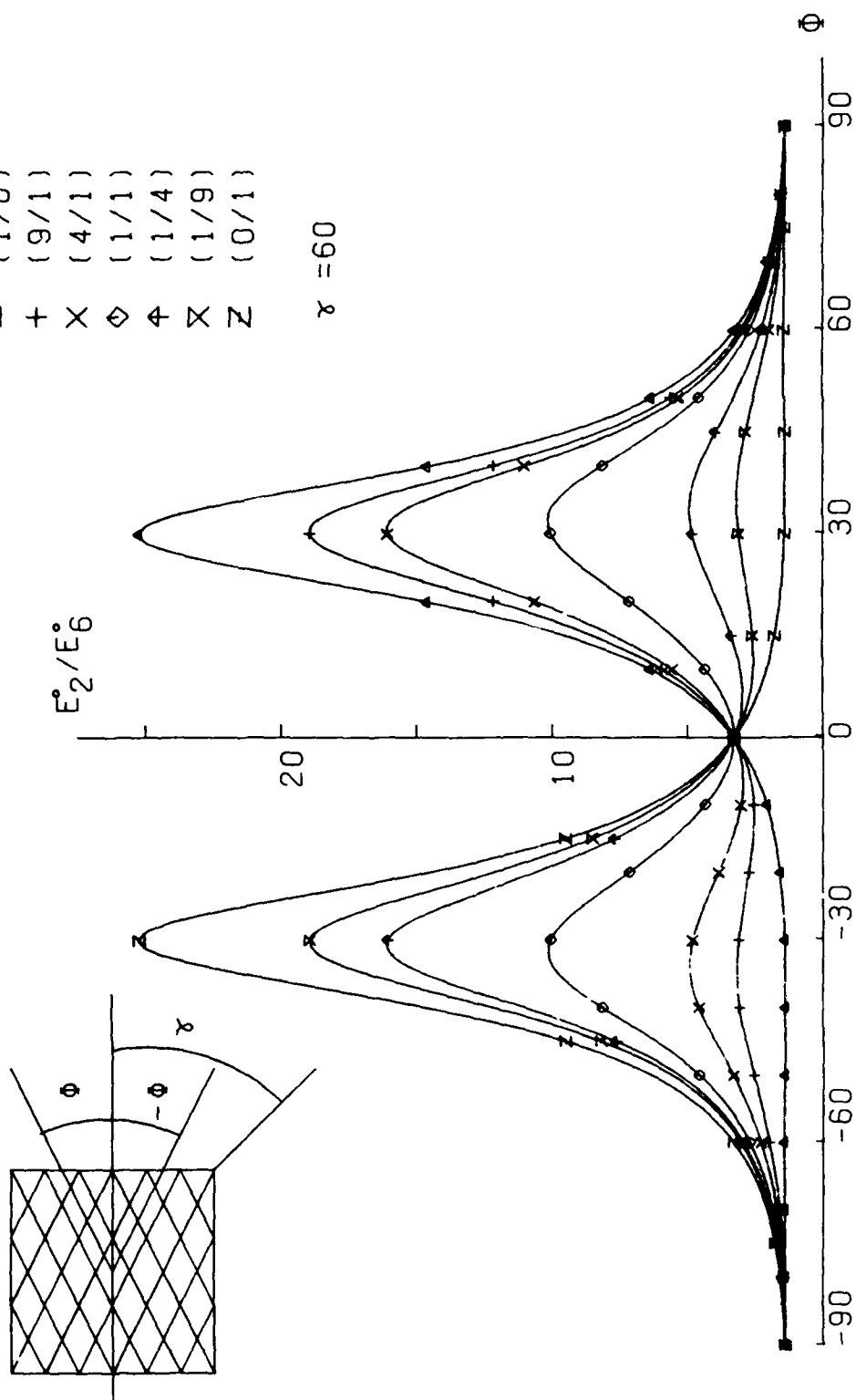


FIG.: 378

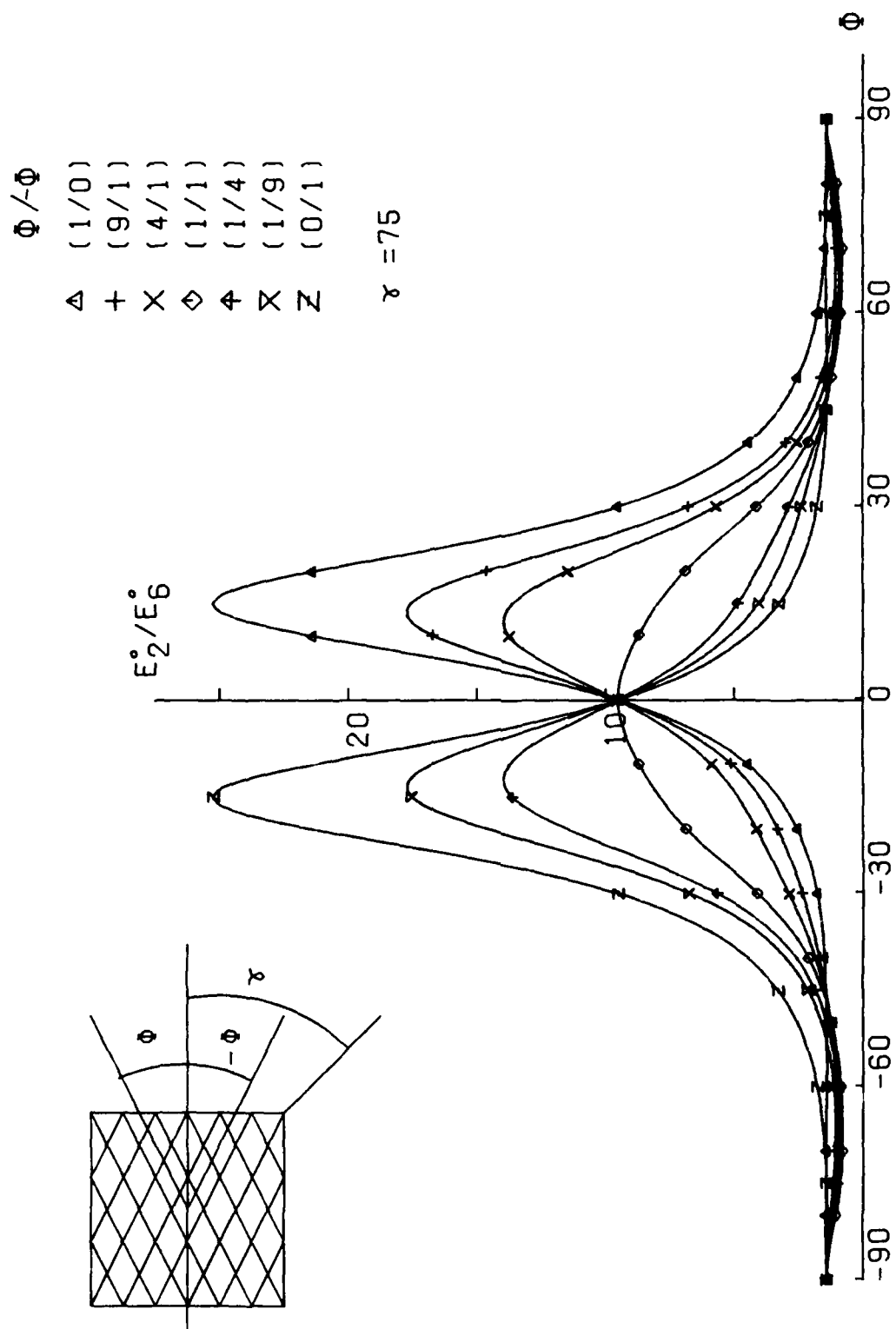


FIG.: 379

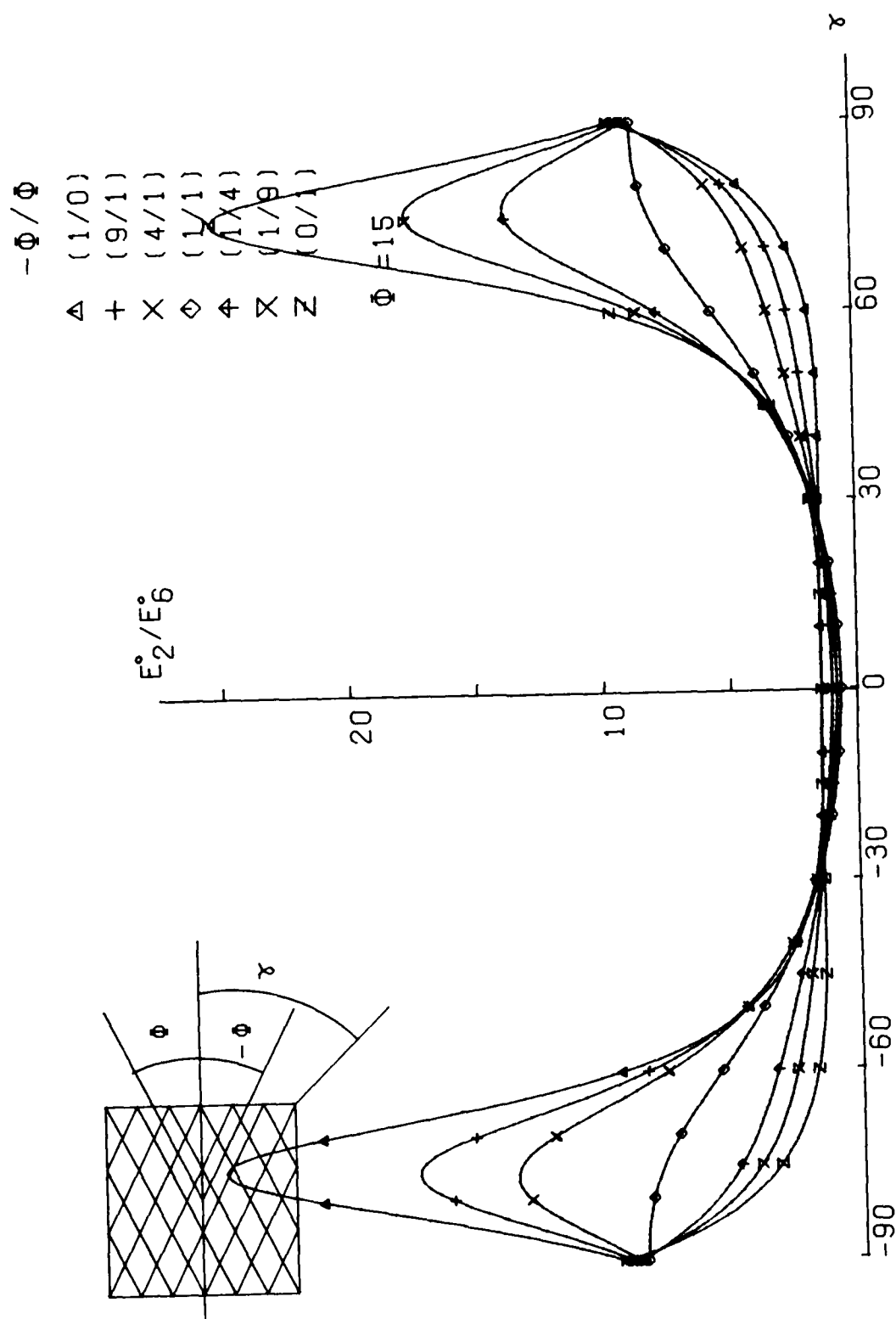


FIG.: 380

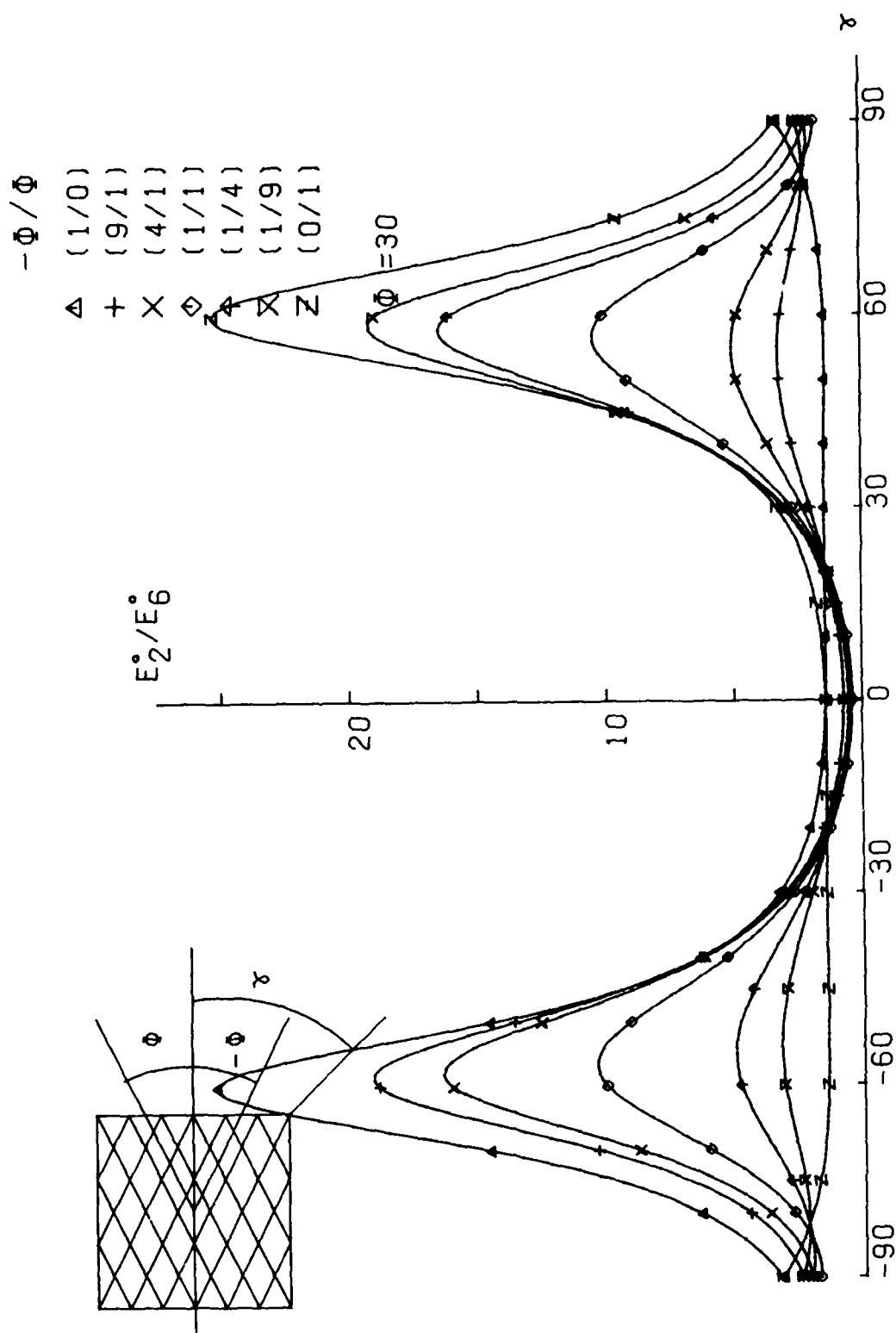


FIG.:381

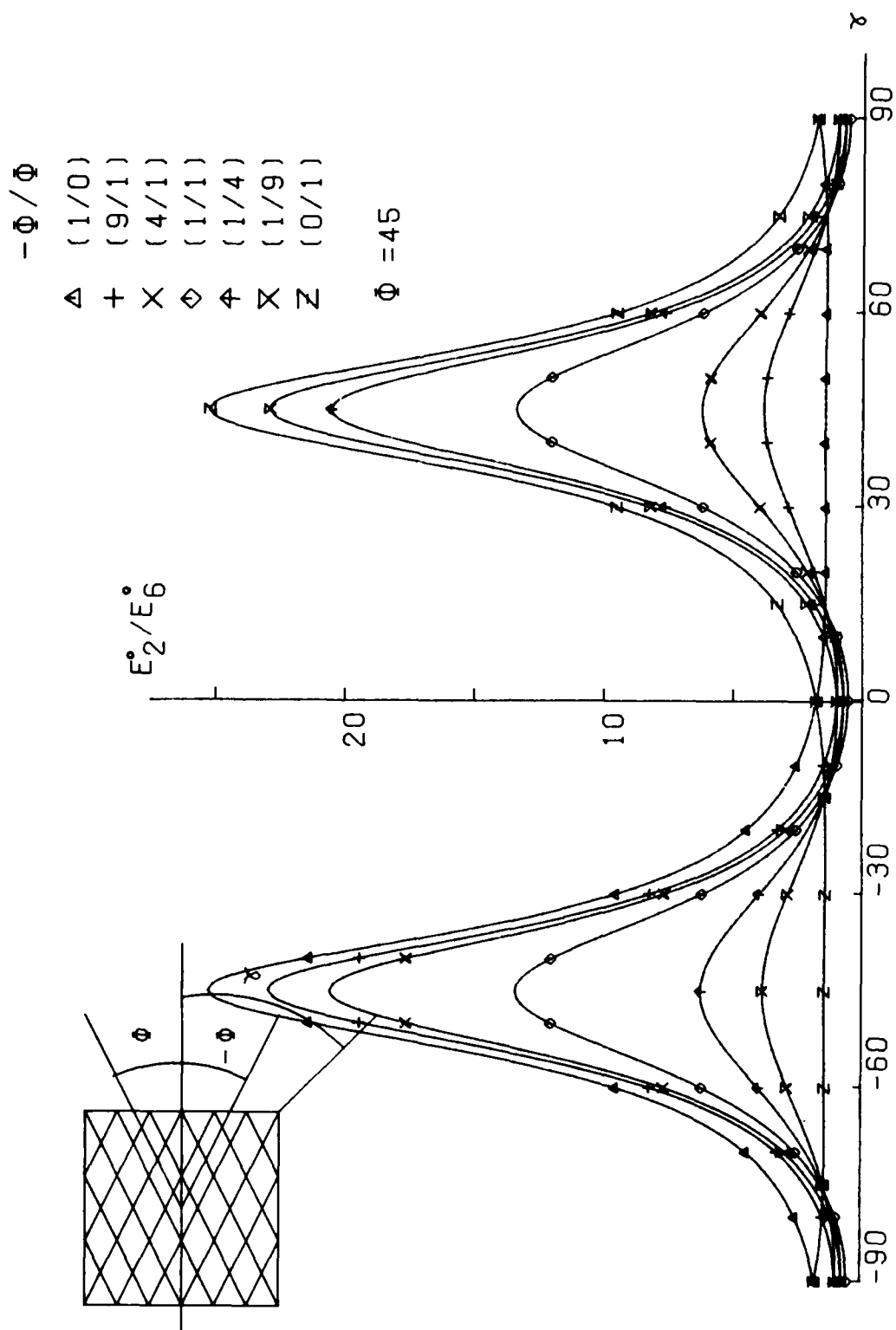
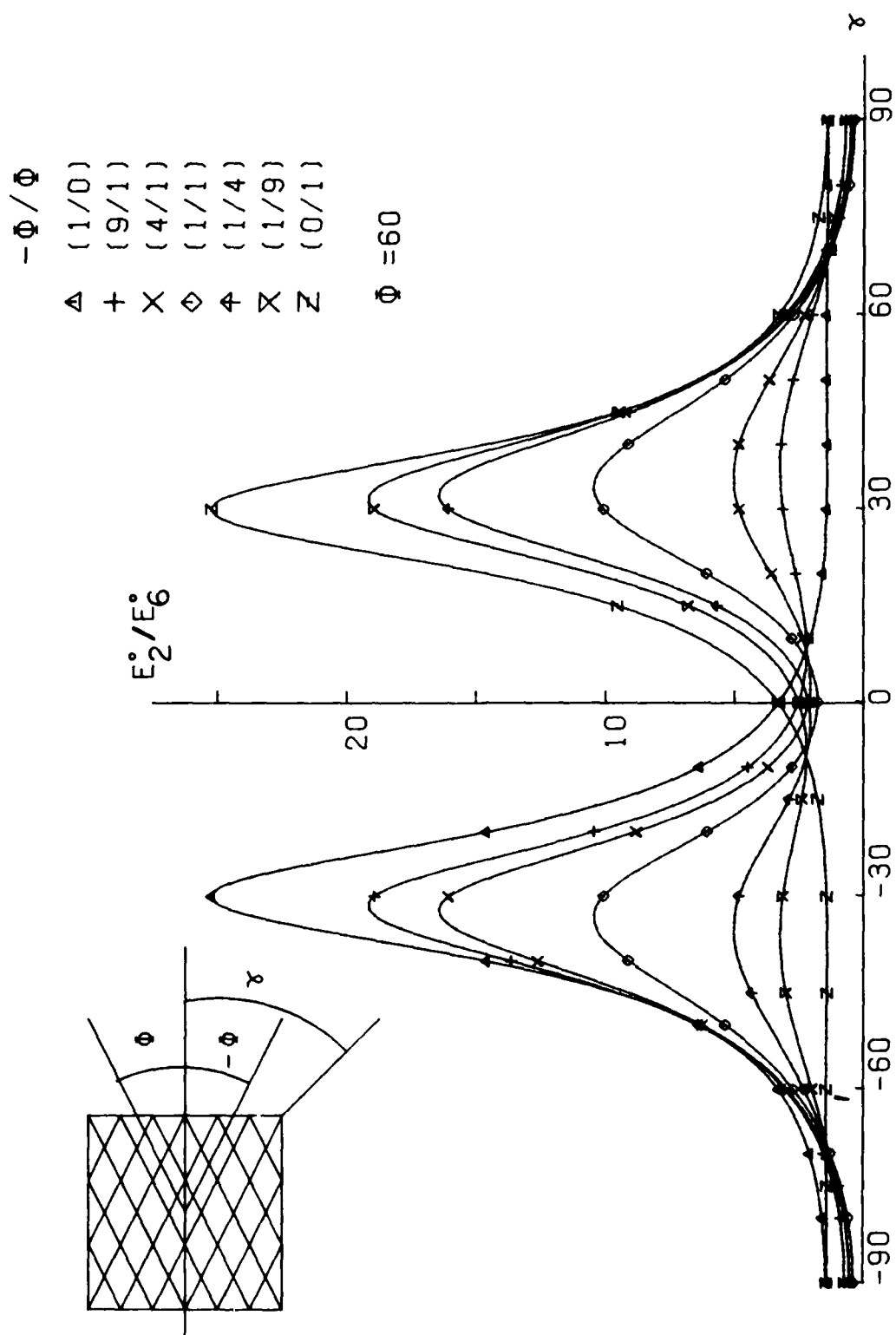
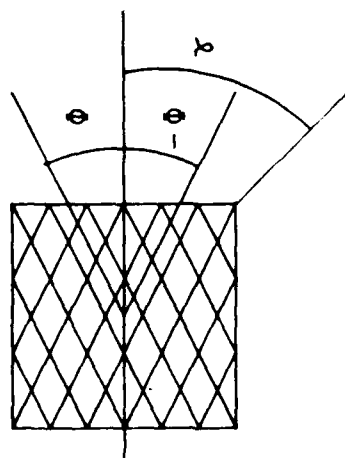


FIG.:382



$\Phi = 60$

FIG.: 383



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)
 $\phi = 75$

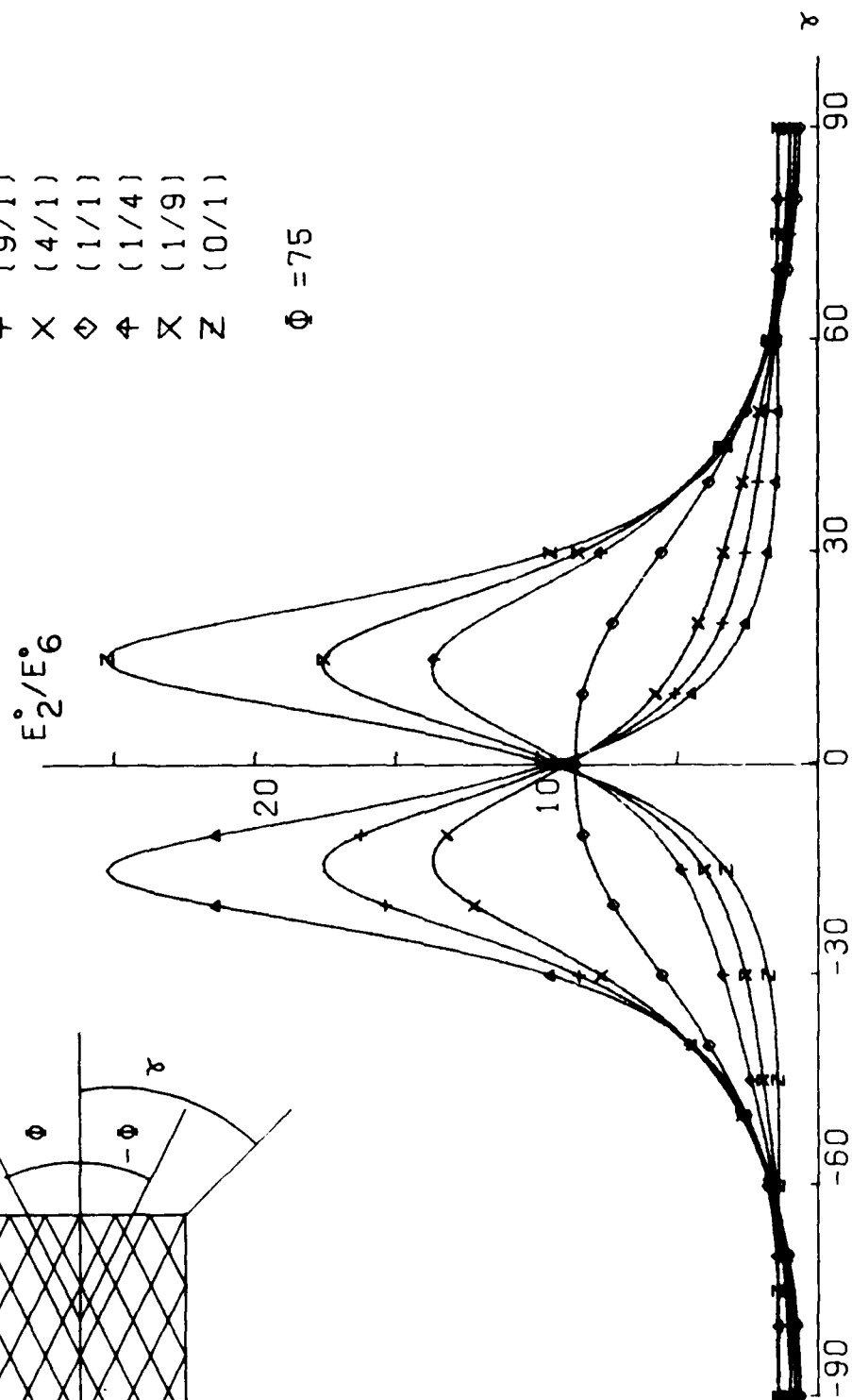
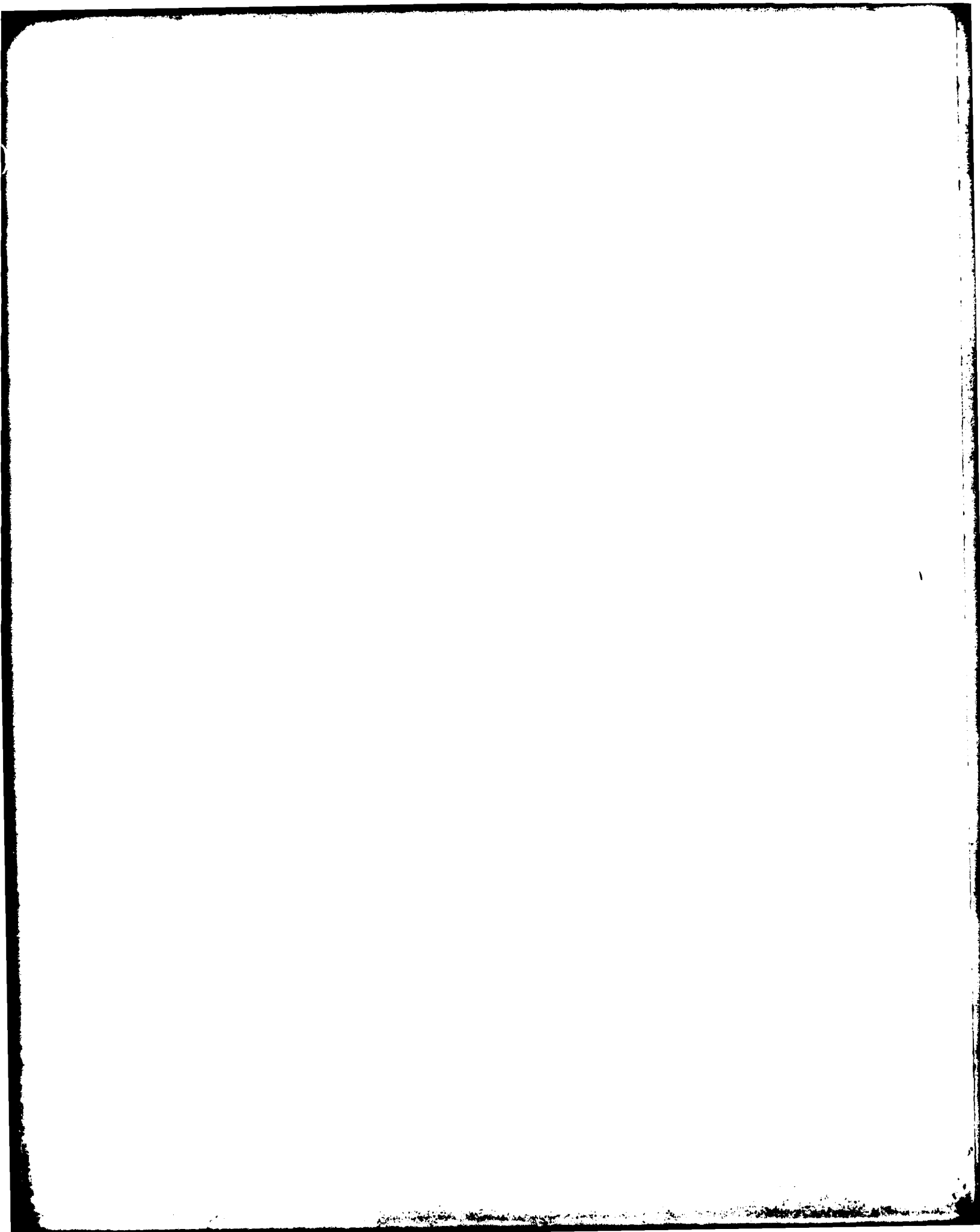
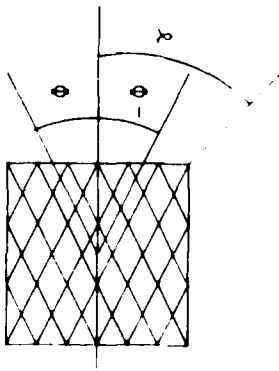


FIG.: 384



STRENGTHS OF DIFFERENT LAMINATES
FOR VARIOUS LOADING CONDITIONS

FIGURE NUMBERS: 385-414



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \clubsuit (1/4)
 \bowtie (1/9)
 Z (0/1)

$\phi = 15$

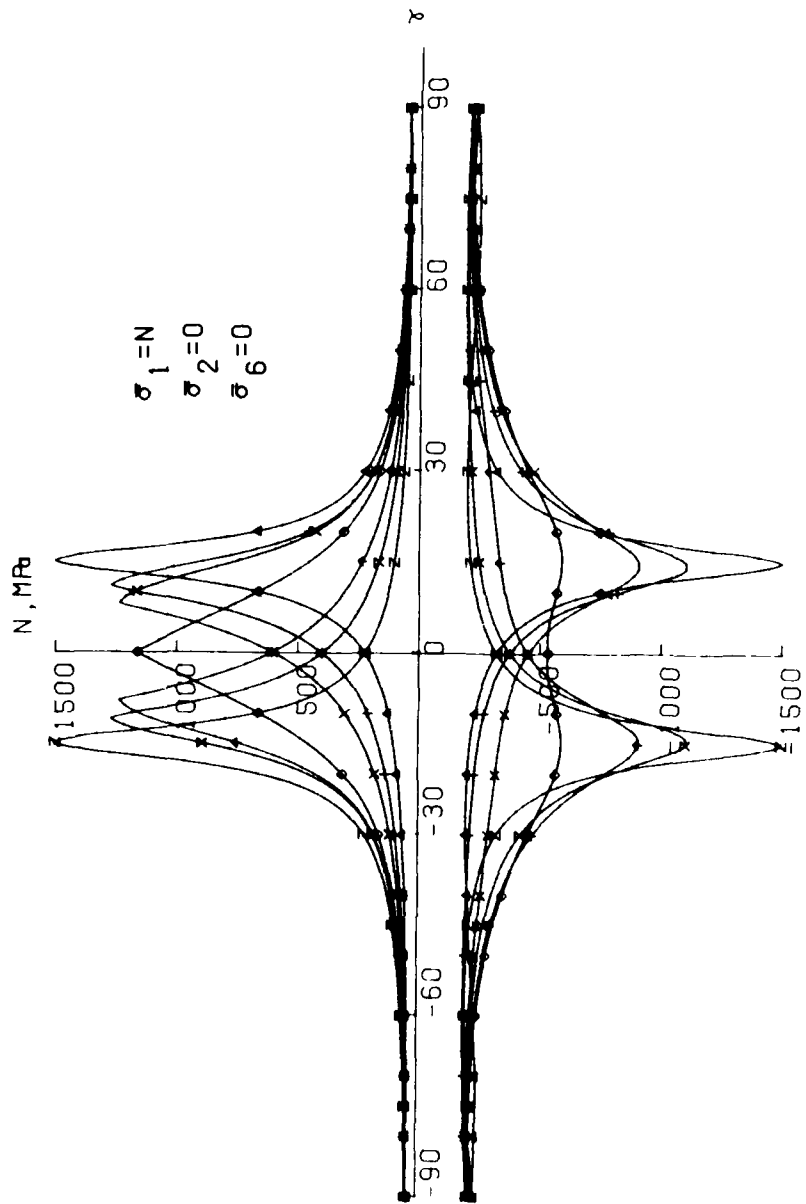


FIG.: 385

$\sigma_1 = N$
 $\sigma_2 = N$
 $\sigma_5 = 0$

$\sigma_1 = N$
 $\sigma_2 = N$
 $\sigma_5 = 0$

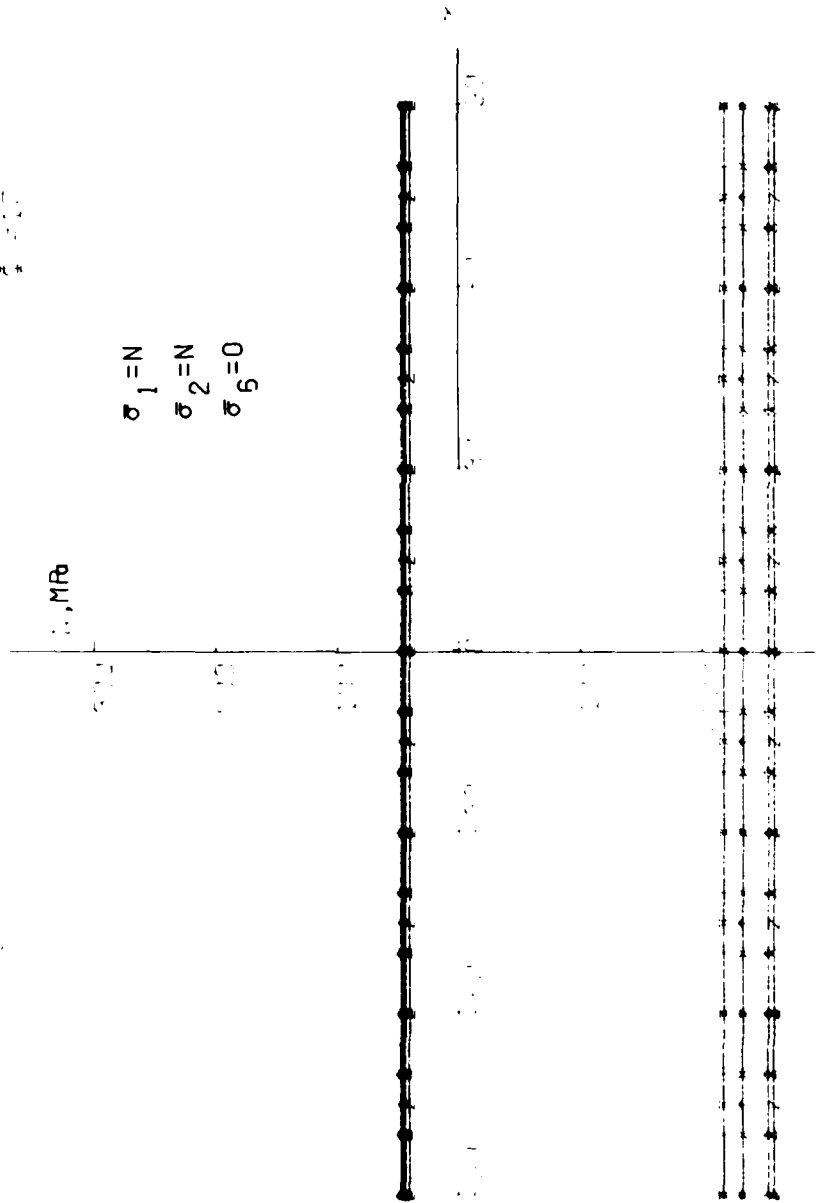


FIG.:386

$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \clubsuit (1/4)
 \bowtie (1/9)
 Σ (0/1)
 $\phi = 15$

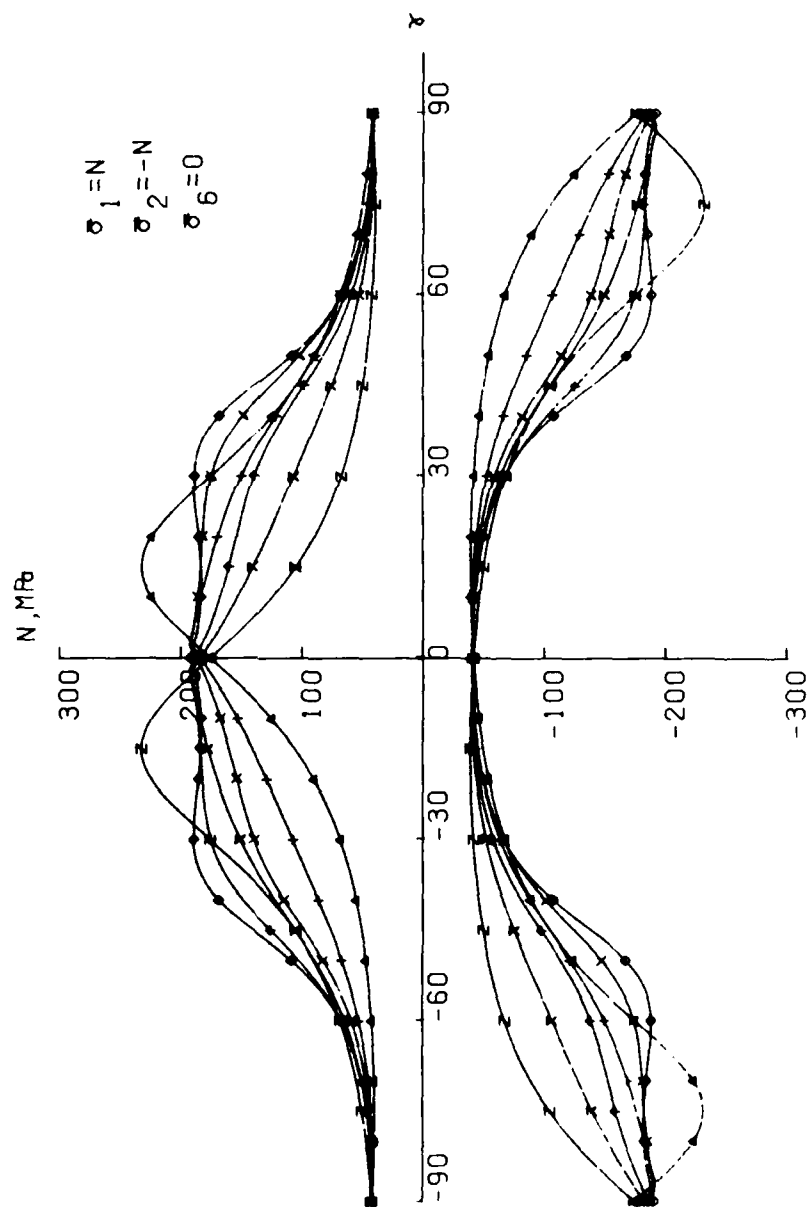
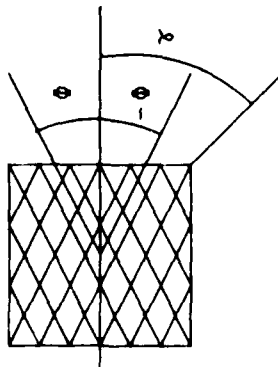
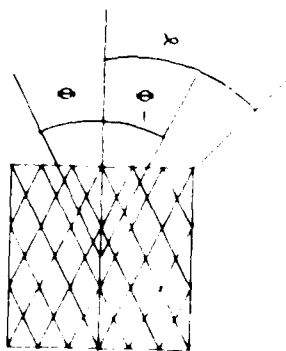


FIG.: 387



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 ϕ (1/1)
 Φ (1/4)
 Σ (1/9)
 Z (0/1)

$\phi = 15$

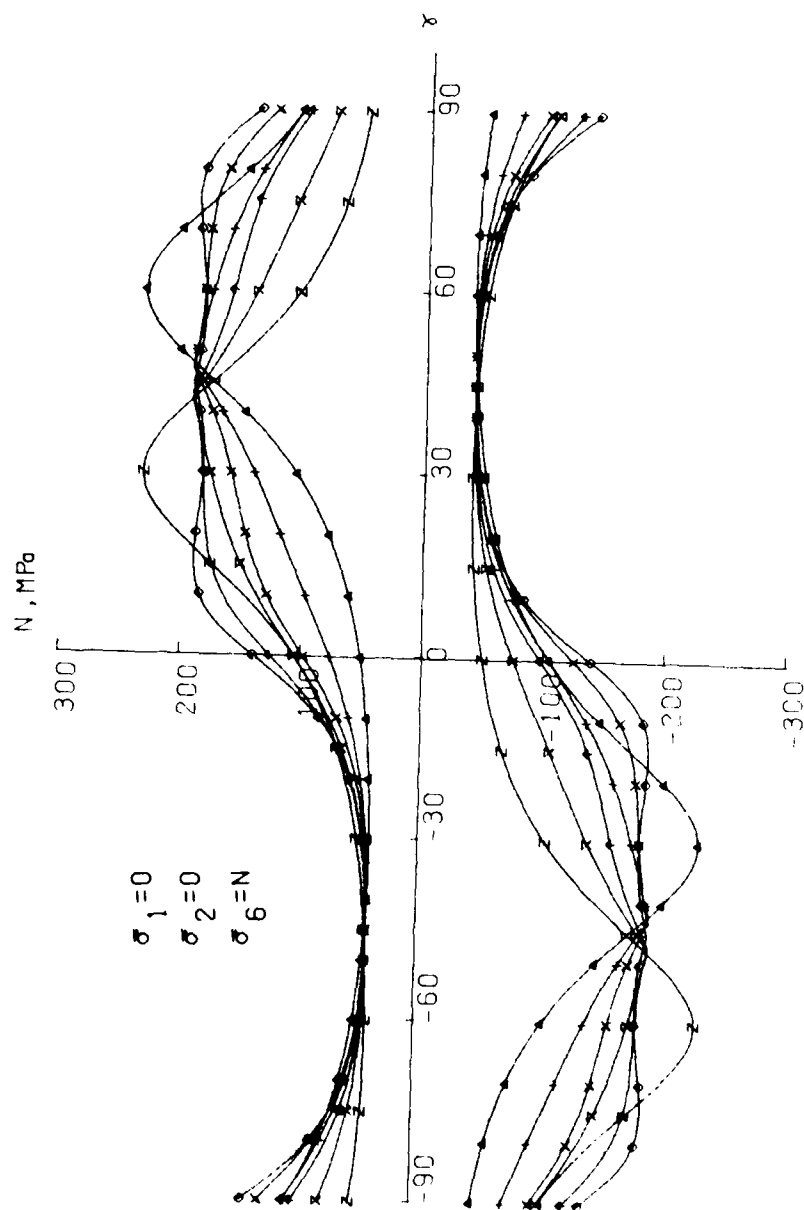
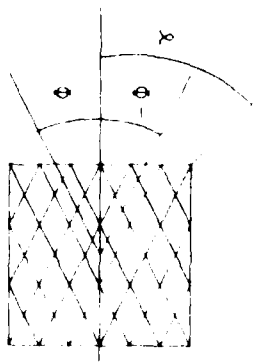


FIG.: 388



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \circ (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\phi = 15$

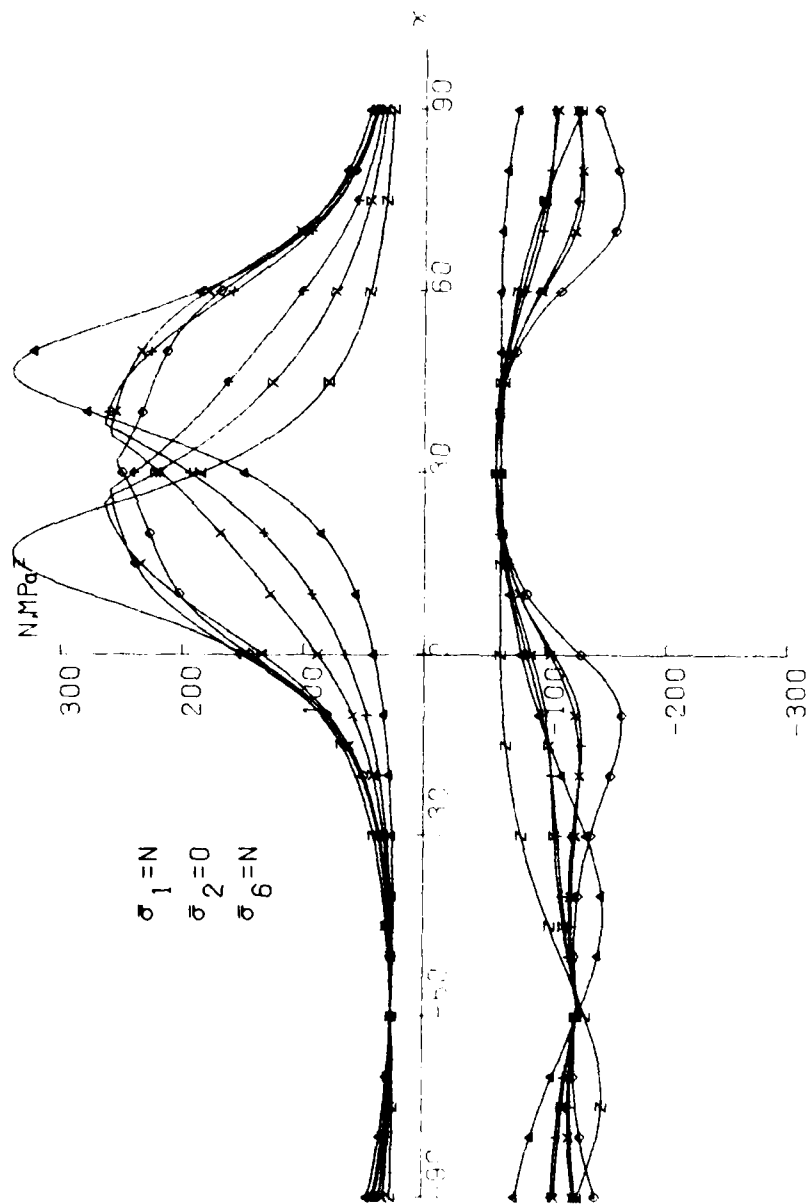
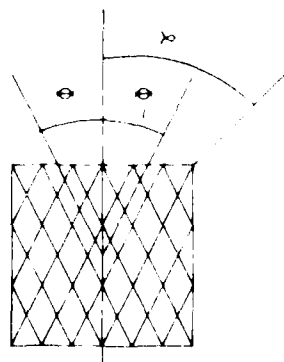


FIG.: 389



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\phi = 15$

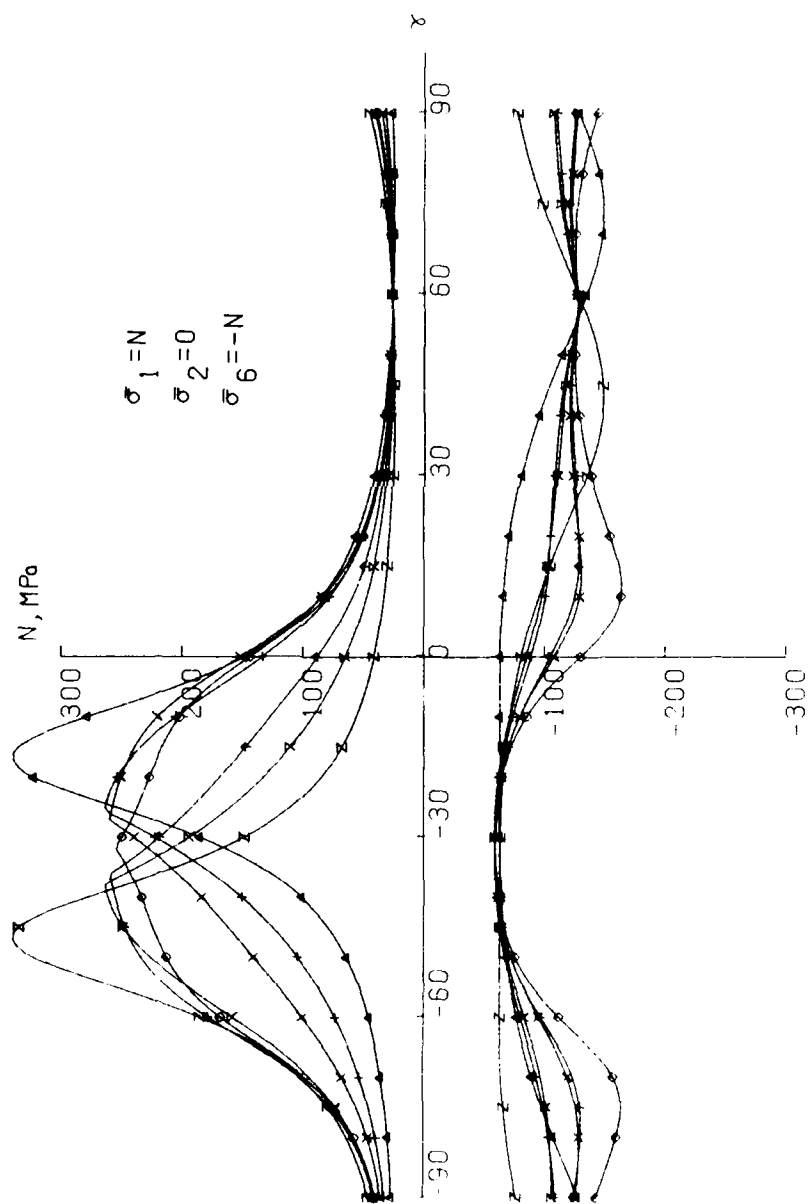
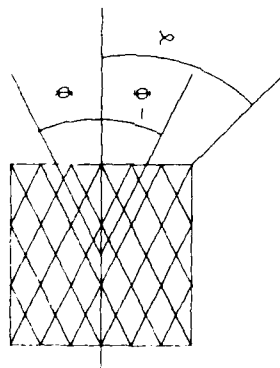


FIG.: 390



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 Σ (0/1)
 $\phi = 30$

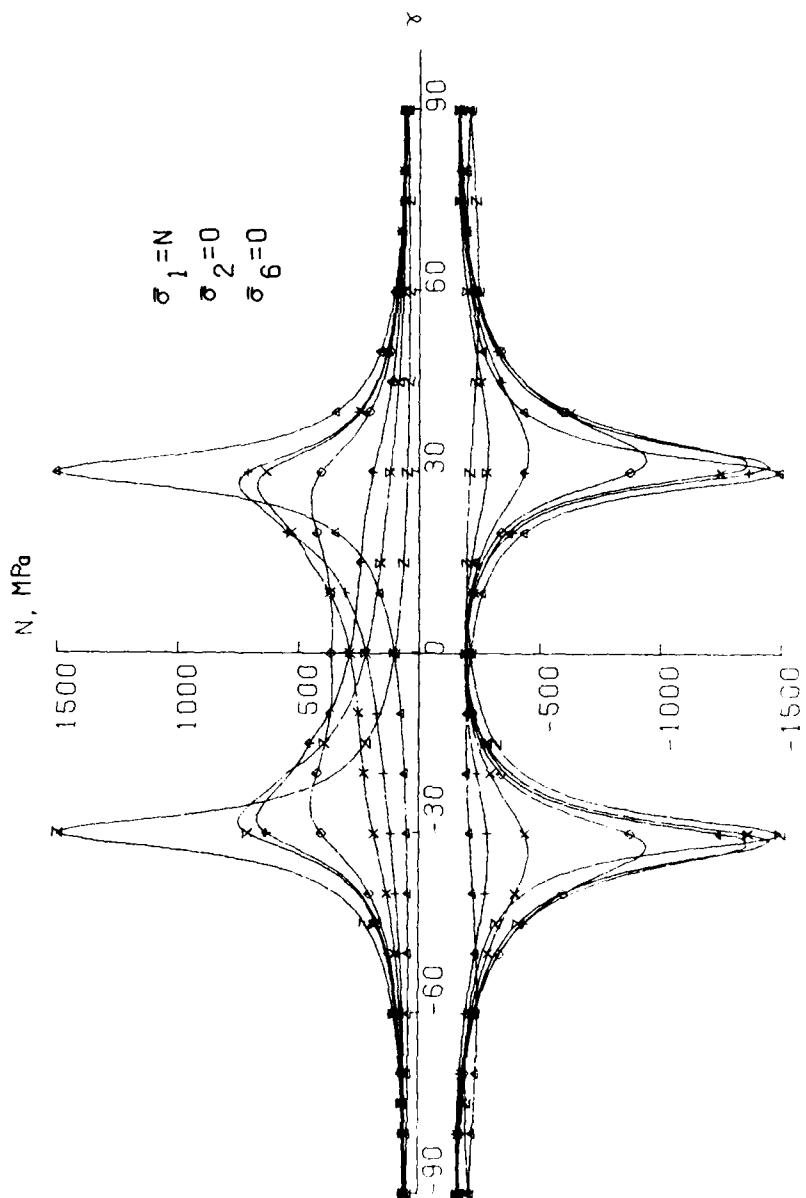
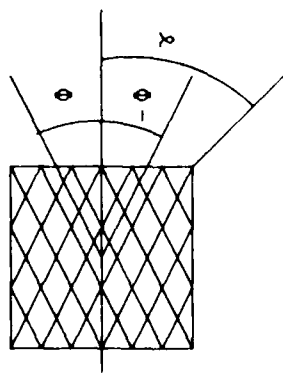


FIG.: 391



$-\phi/\phi$

Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\phi = 30$

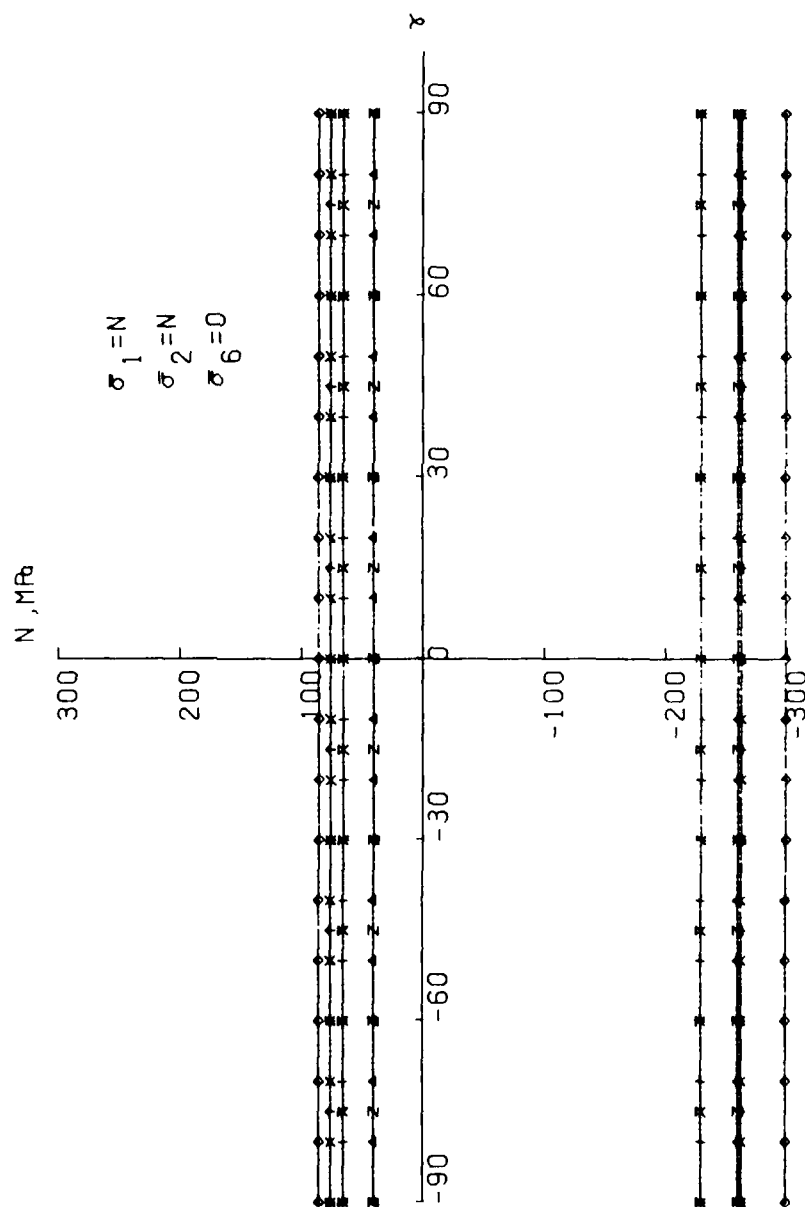
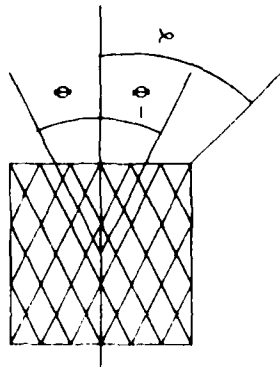


FIG.: 392



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 $\#$ (1/4)
 \times (1/9)
 Z (0/1)
 $\Phi = 30$

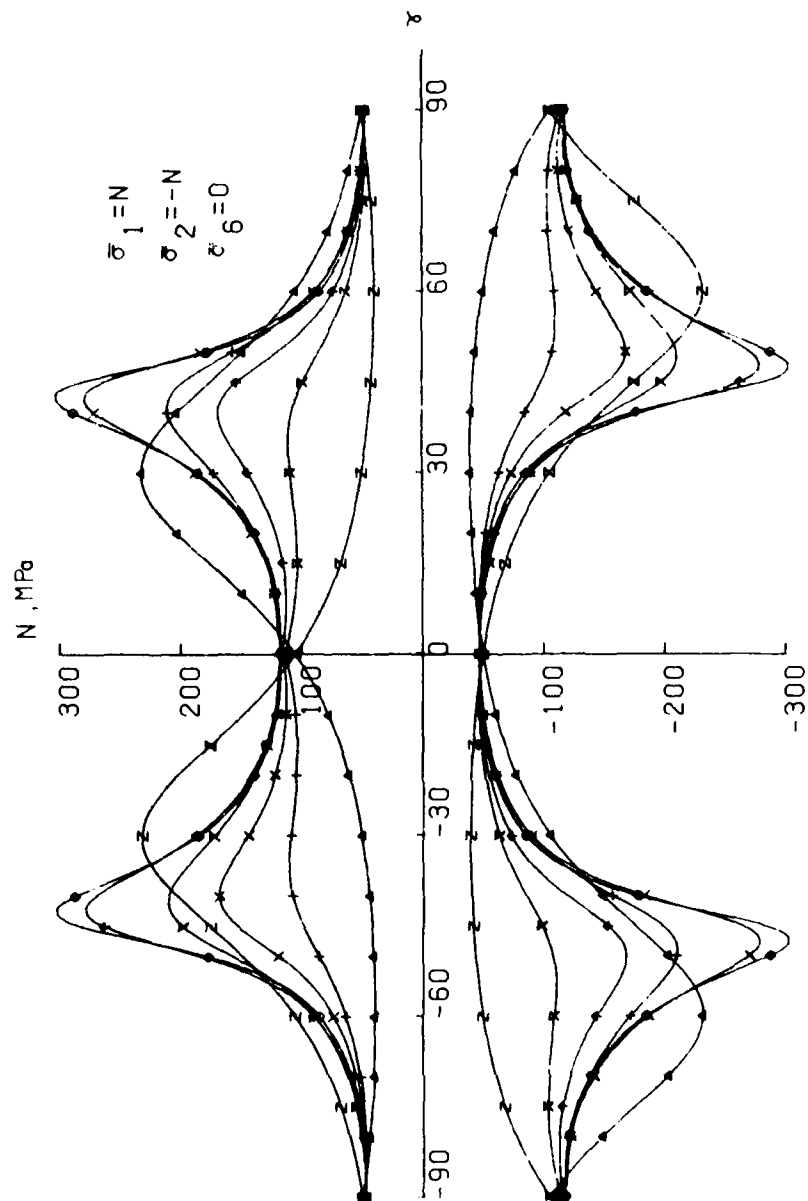
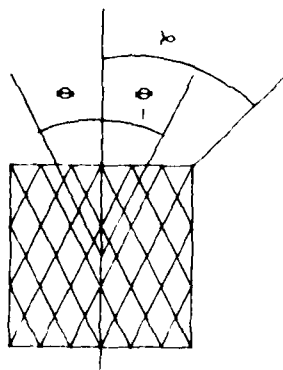


FIG.: 393



$-\phi/\phi$

Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 ∇ (1/4)
 \times (1/9)
 z (0/1)

$\phi = 30$

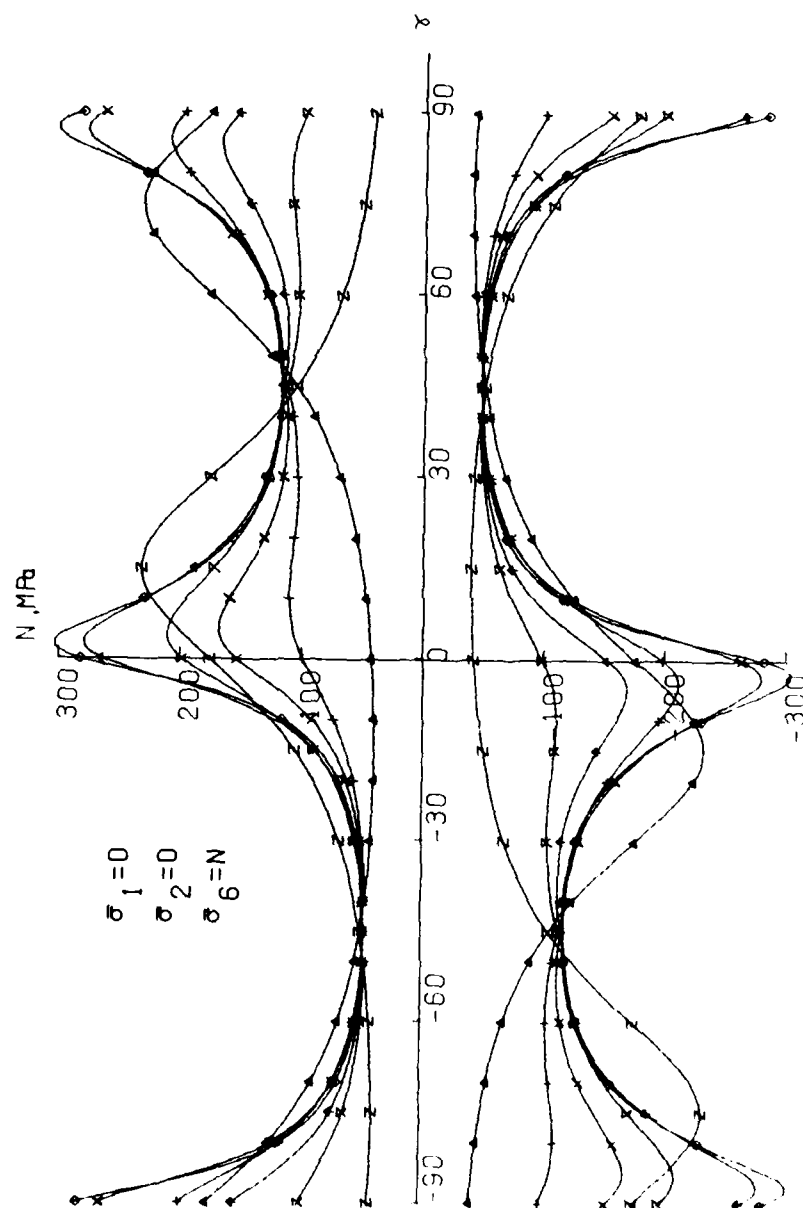
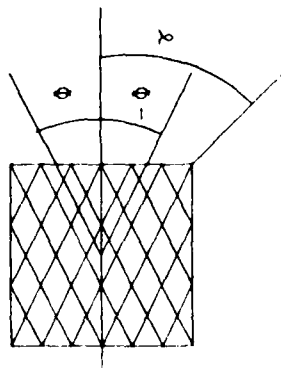


FIG.: 394



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\phi = 30$

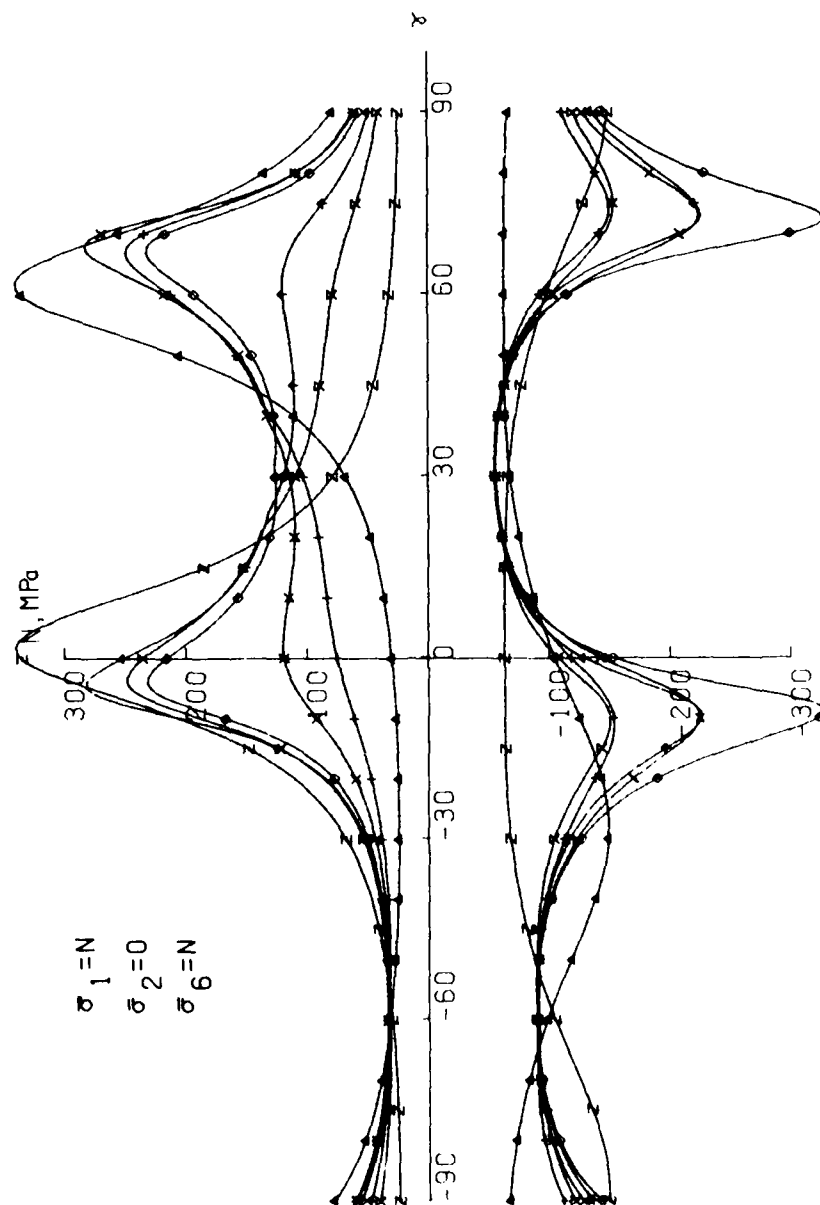
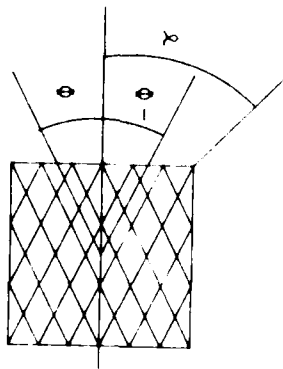


FIG.: 395



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \times (1/9)
 Σ (0/1)
 $\Phi = 30$

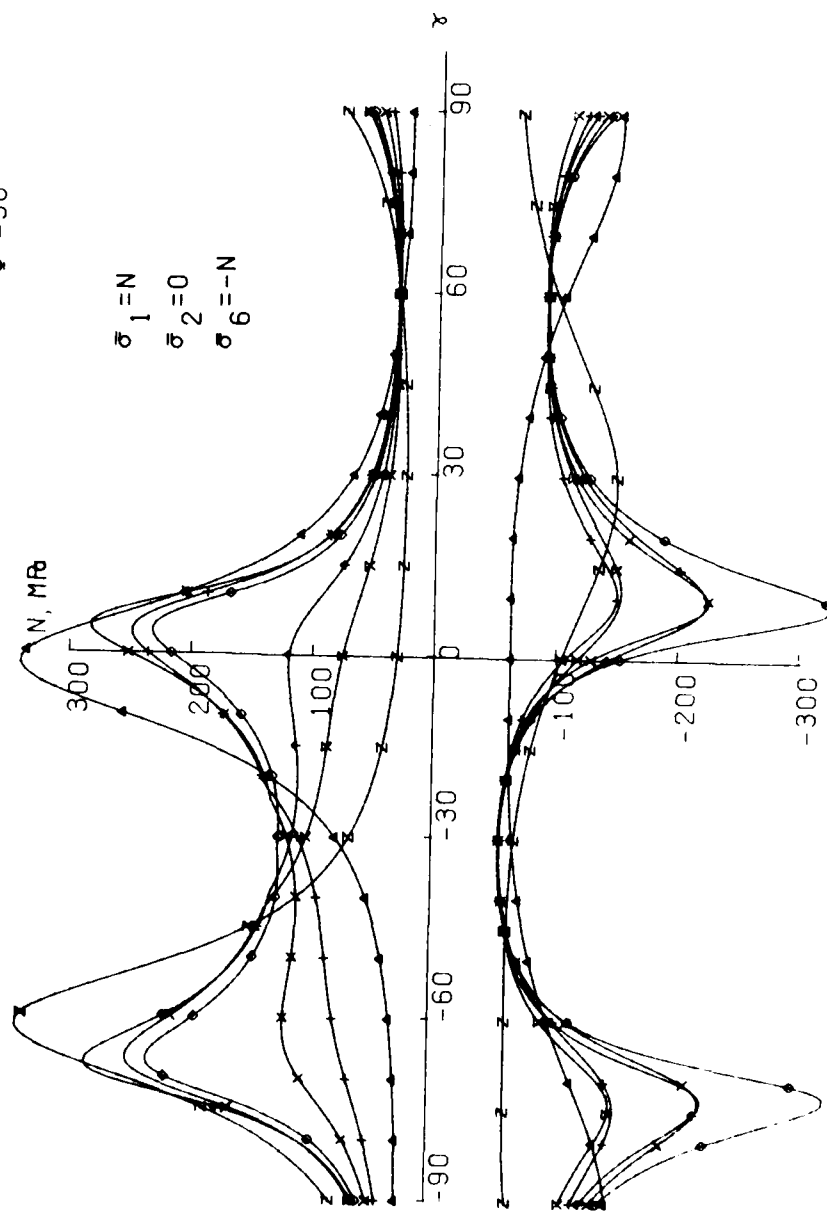
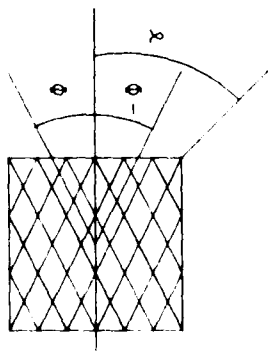


FIG.: 396



$-\phi/\phi$

Δ	(1/0)
+	(9/1)
x	(4/1)
\diamond	(1/1)
\oplus	(1/4)
x	(1/9)
Z	(0/1)

$\phi = 45$

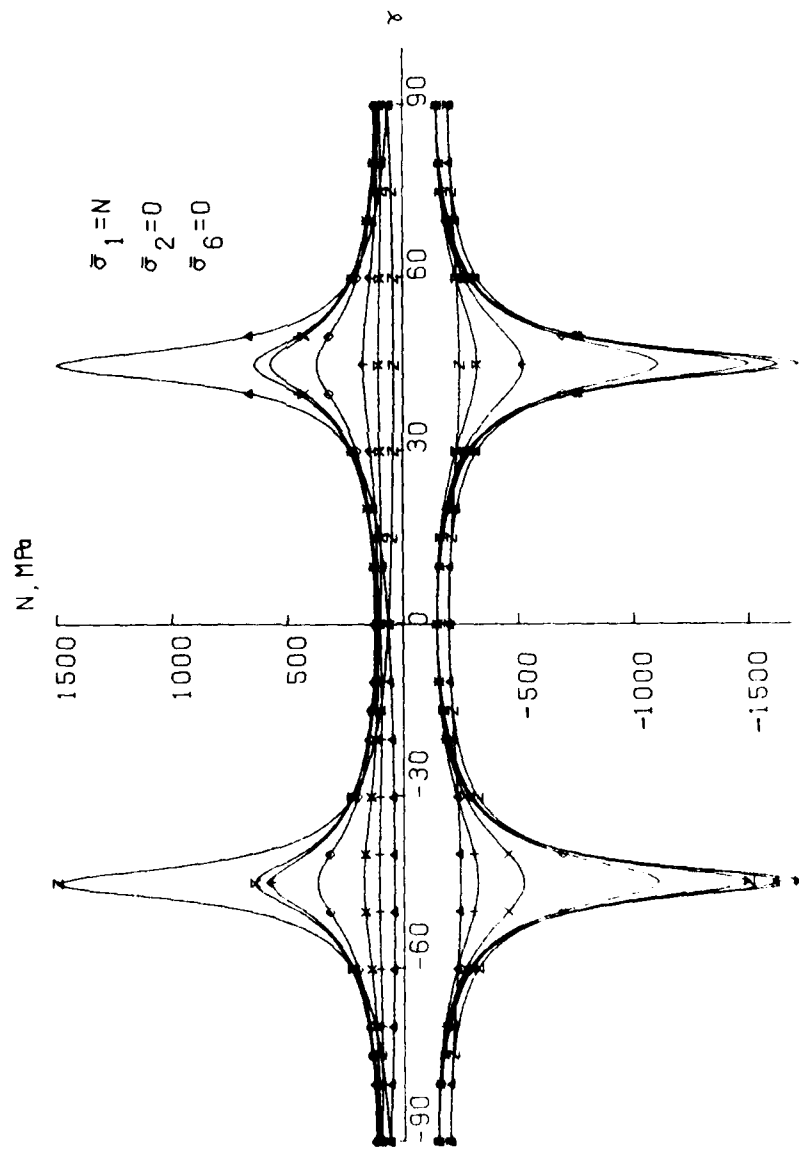
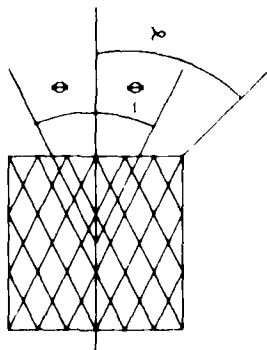


FIG.: 397



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Z (0/1)

$\Phi = 45$

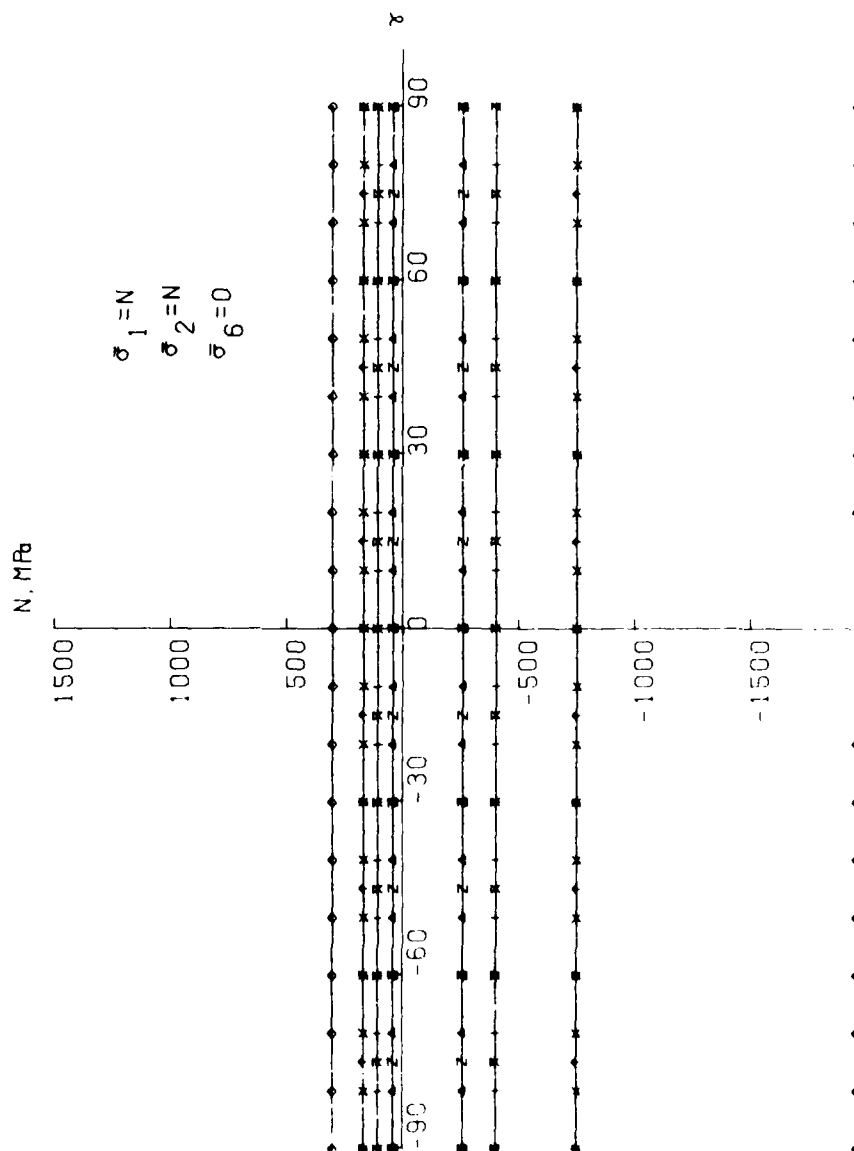
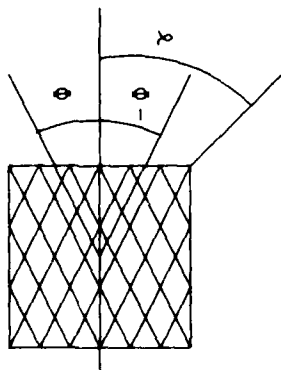


FIG.: 398



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\phi = 45$

$\sigma_1 = N$
 $\sigma_2 = -N$
 $\sigma_6 = 0$

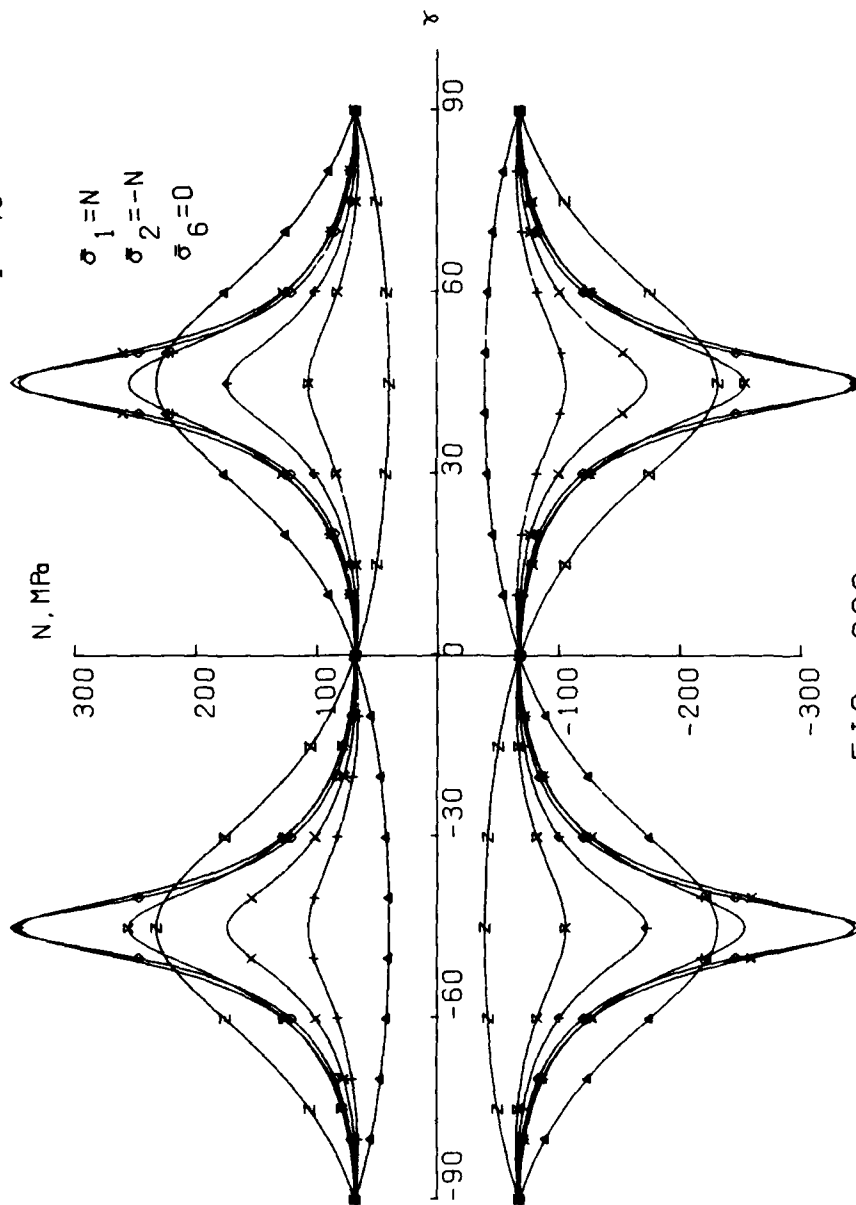
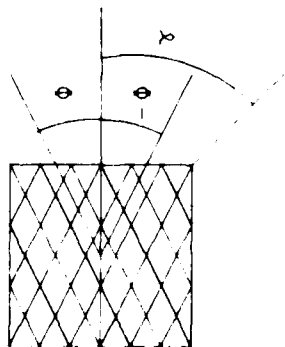


FIG.: 399



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\Phi = 45$

$\sigma_1 = 0$
 $\sigma_2 = 0$
 $\sigma_6 = N$

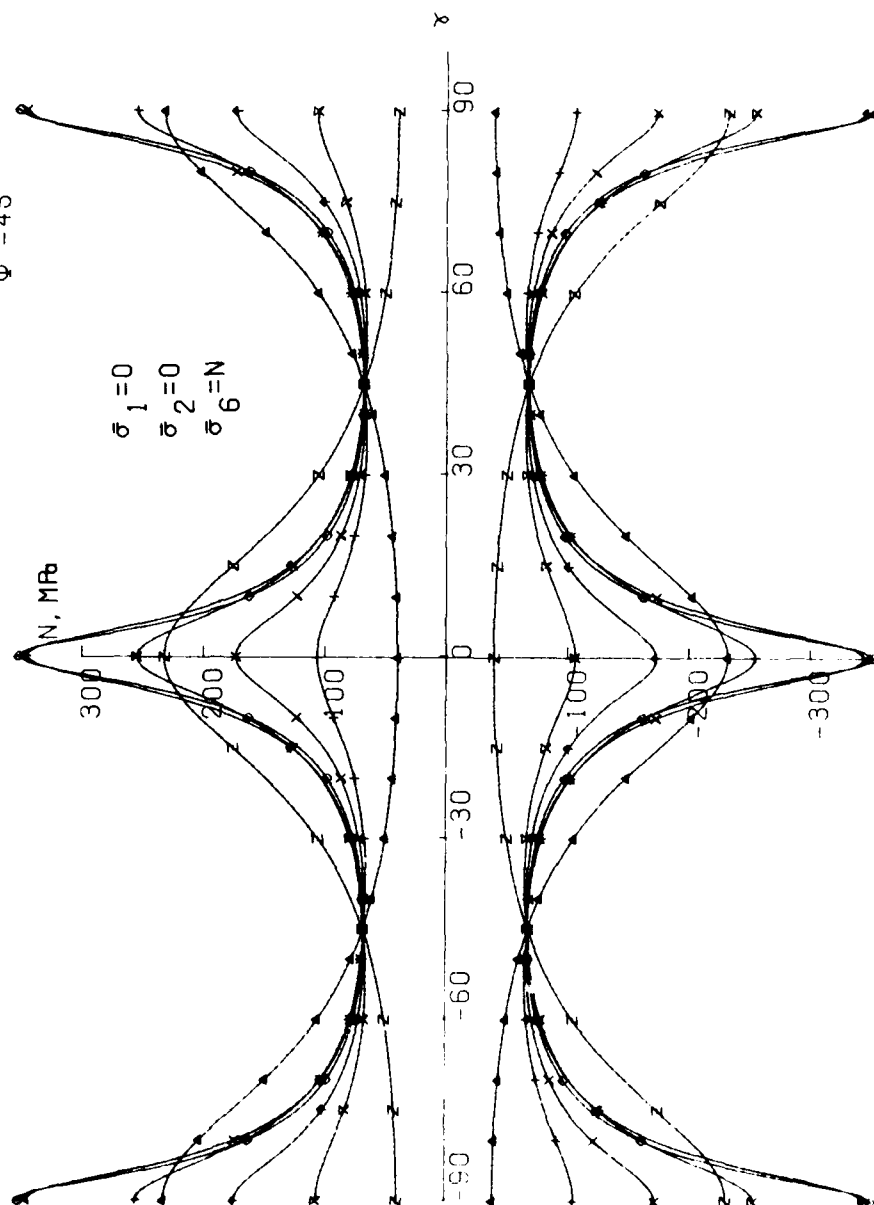
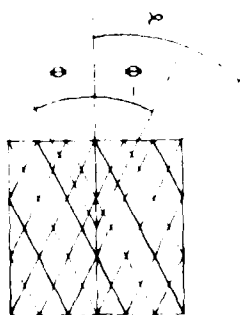


FIG.: 400



ϕ ϕ
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \circ (1/1)
 \oplus (1/4)
 \times (1/9)
 Δ (0/1)

$\phi = 45$

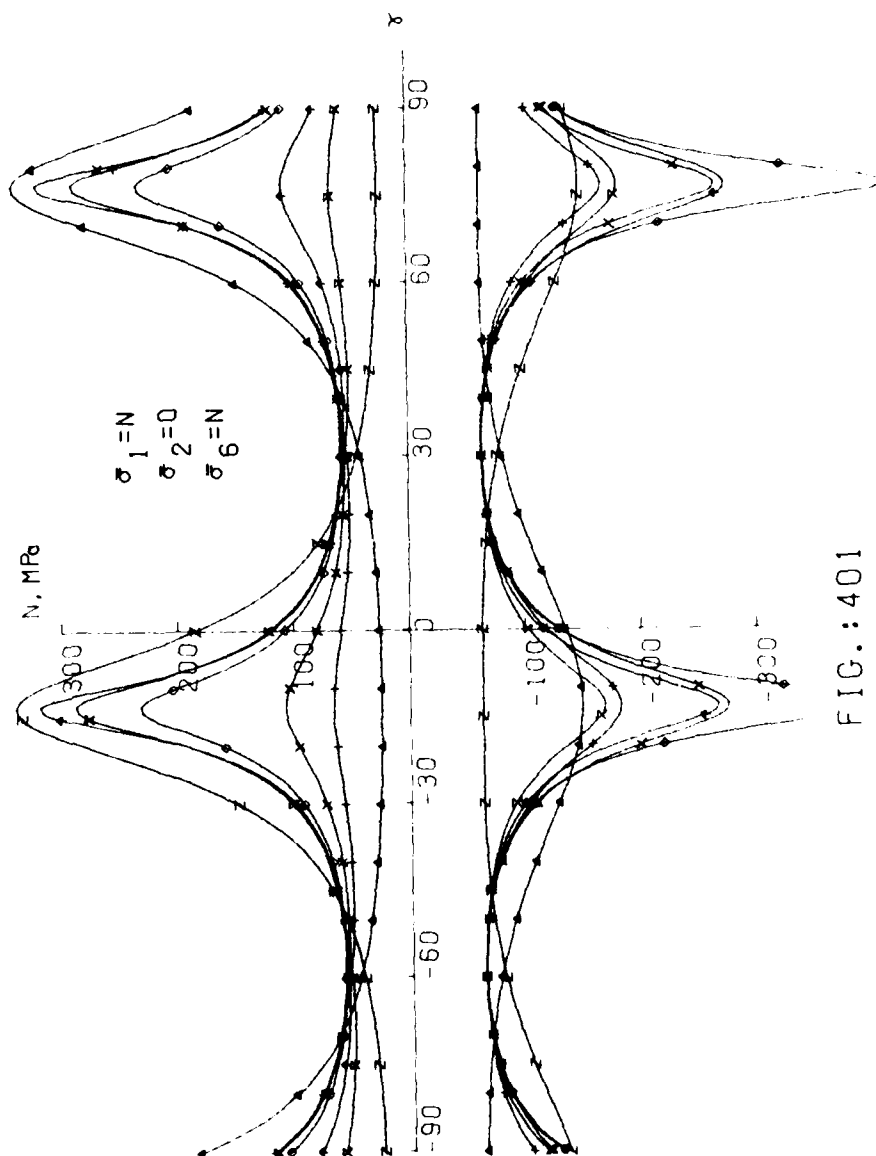


FIG.: 401

Δ 1.0
 $+$ 1.5
 \times 2.0
 \circ 2.5
 $+$ 3.0
 \times 3.5
 Δ 4.0

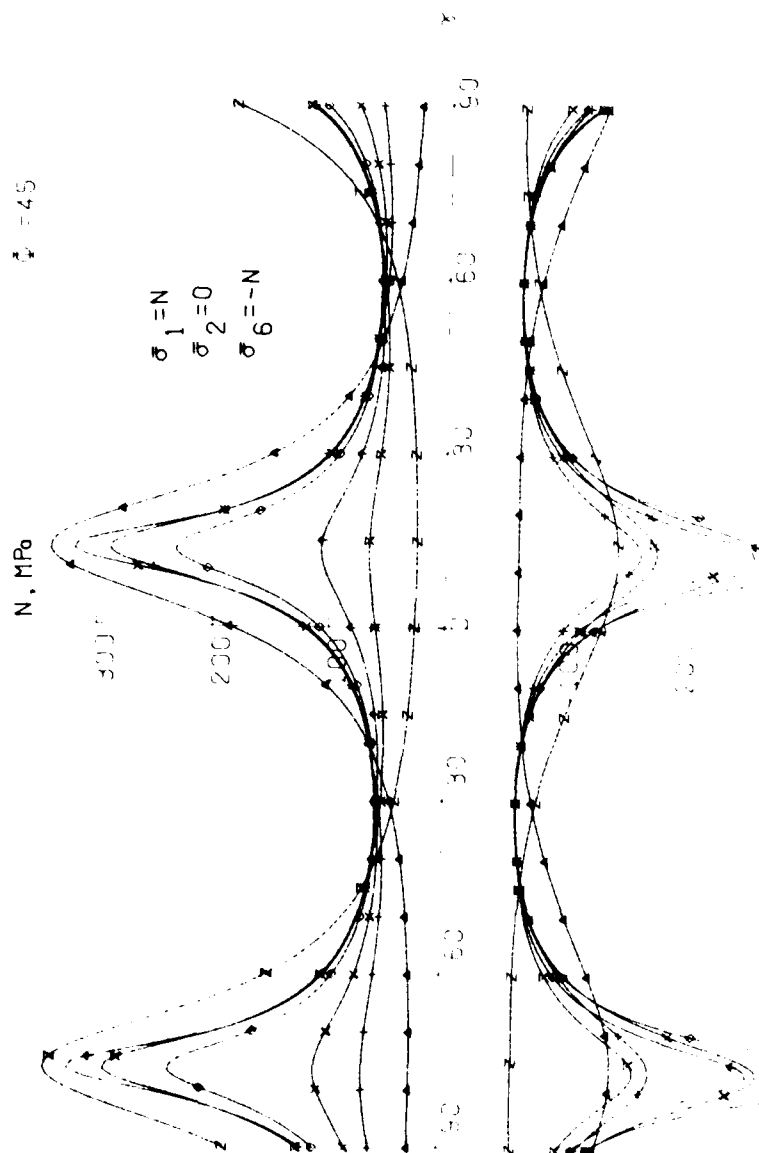
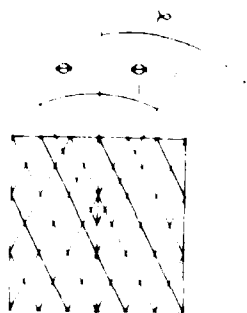
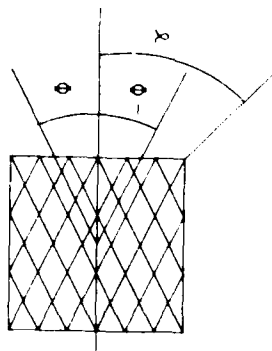


FIG.: 402



ϕ/ϕ

Δ (1/2)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\phi = 60$

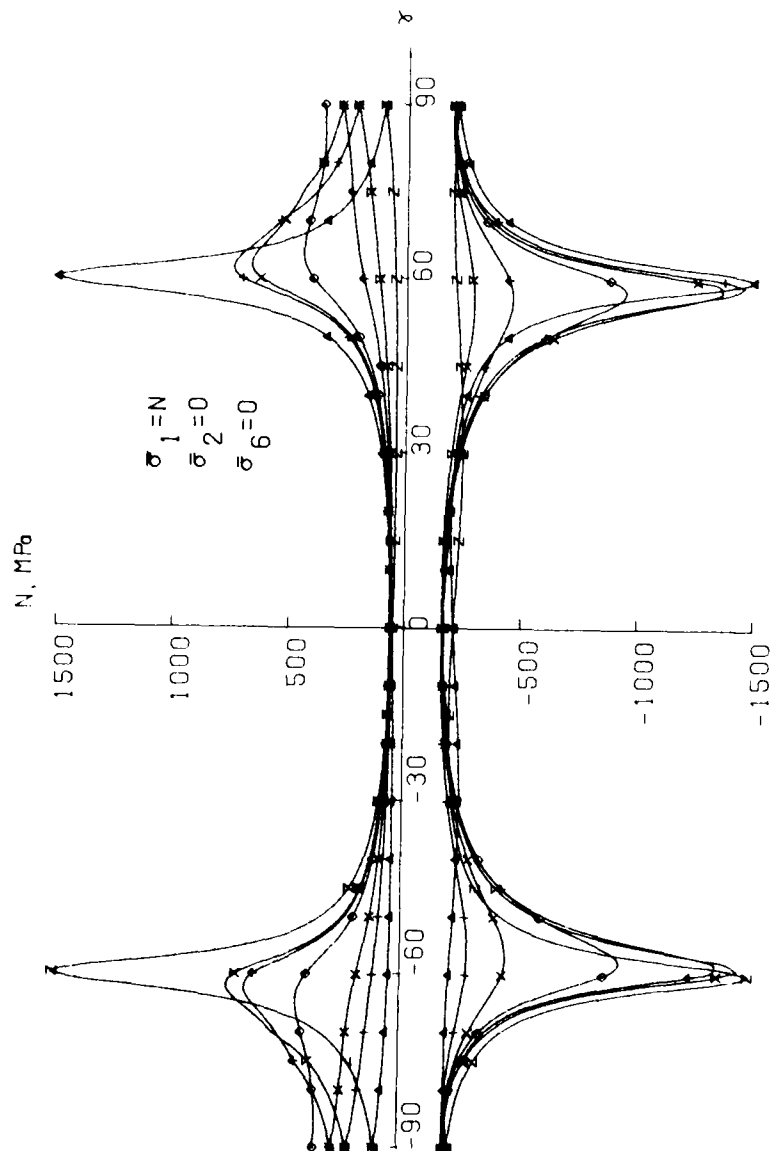
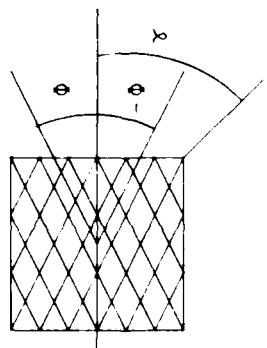


FIG.: 403



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)
 $\Phi = 60$

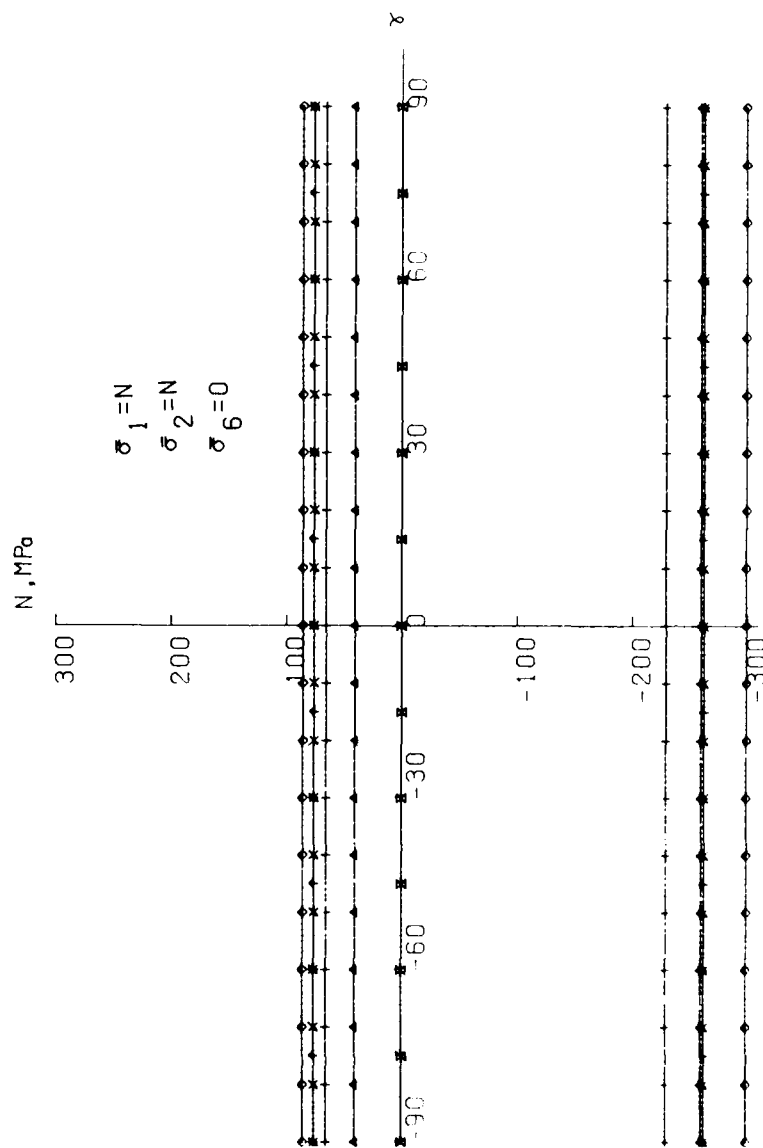


FIG.: 404

$\sigma_1 = N$
 $\sigma_2 = -N$
 $\sigma_6 = 0$

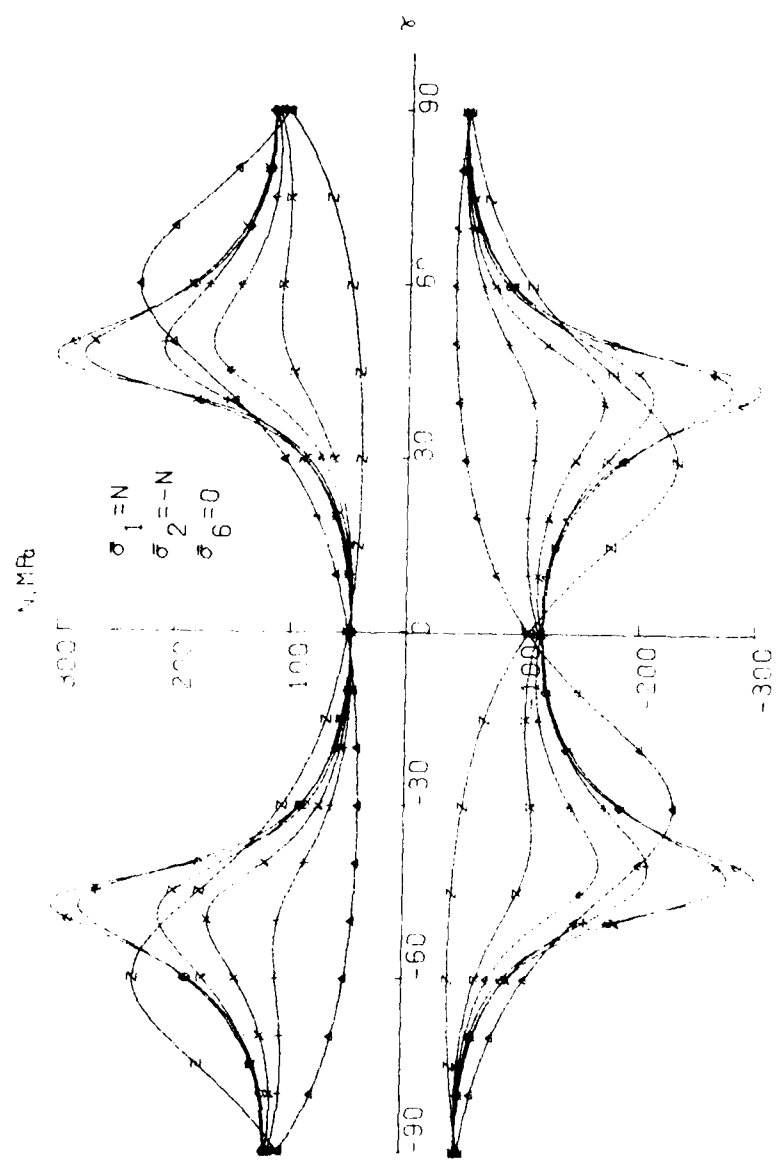
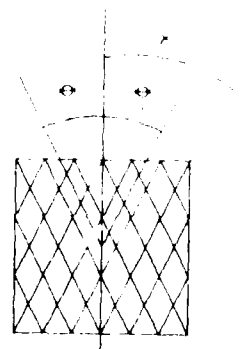
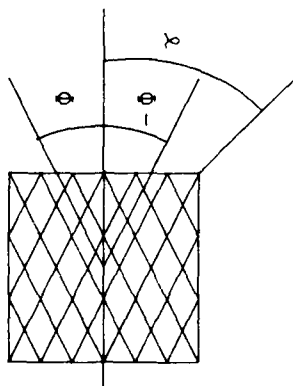


FIG.: 405



$-\phi/\phi$
 $\Delta (1/0)$
 $+(9/1)$
 $\times (4/1)$
 $\diamond (1/1)$
 $\oplus (1/4)$
 $\times (1/9)$
 $\Sigma (0/1)$

$\phi = 60$

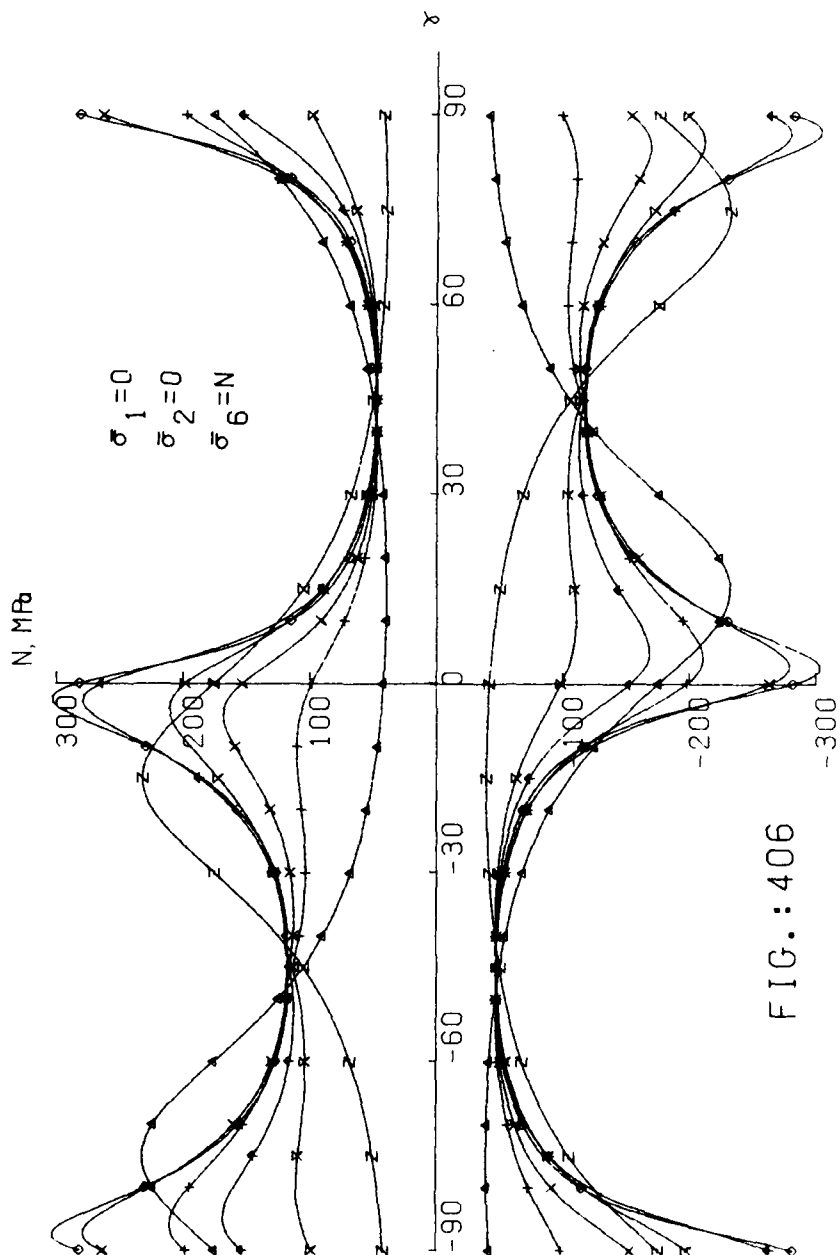


FIG.: 406

$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 z (0/1)

$\Phi = 60$

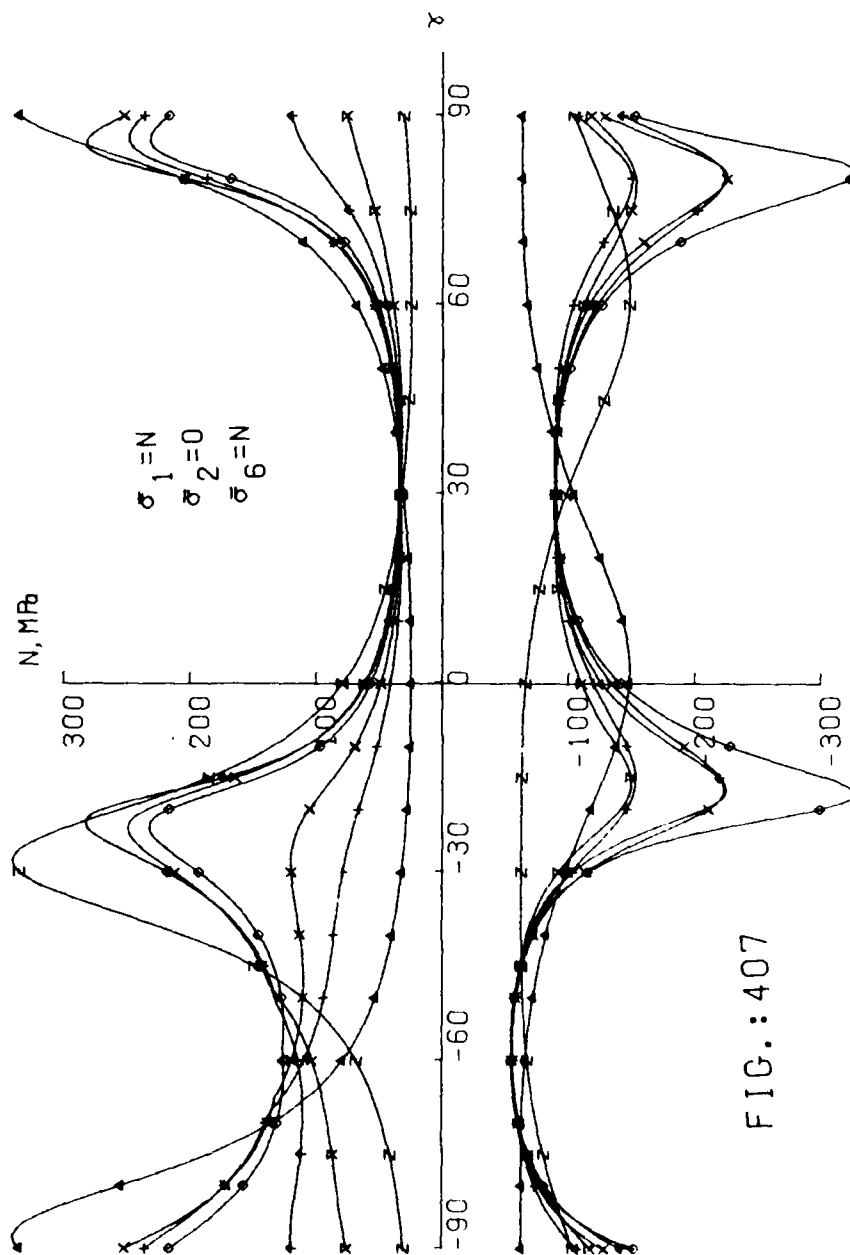
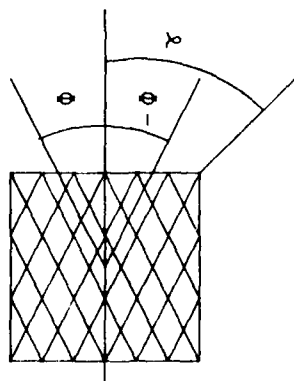
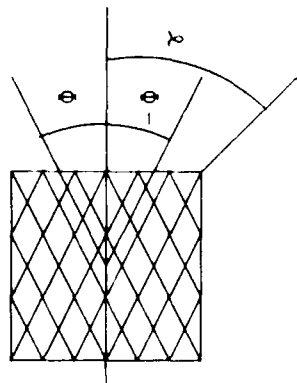


FIG.: 407



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\phi = 60$

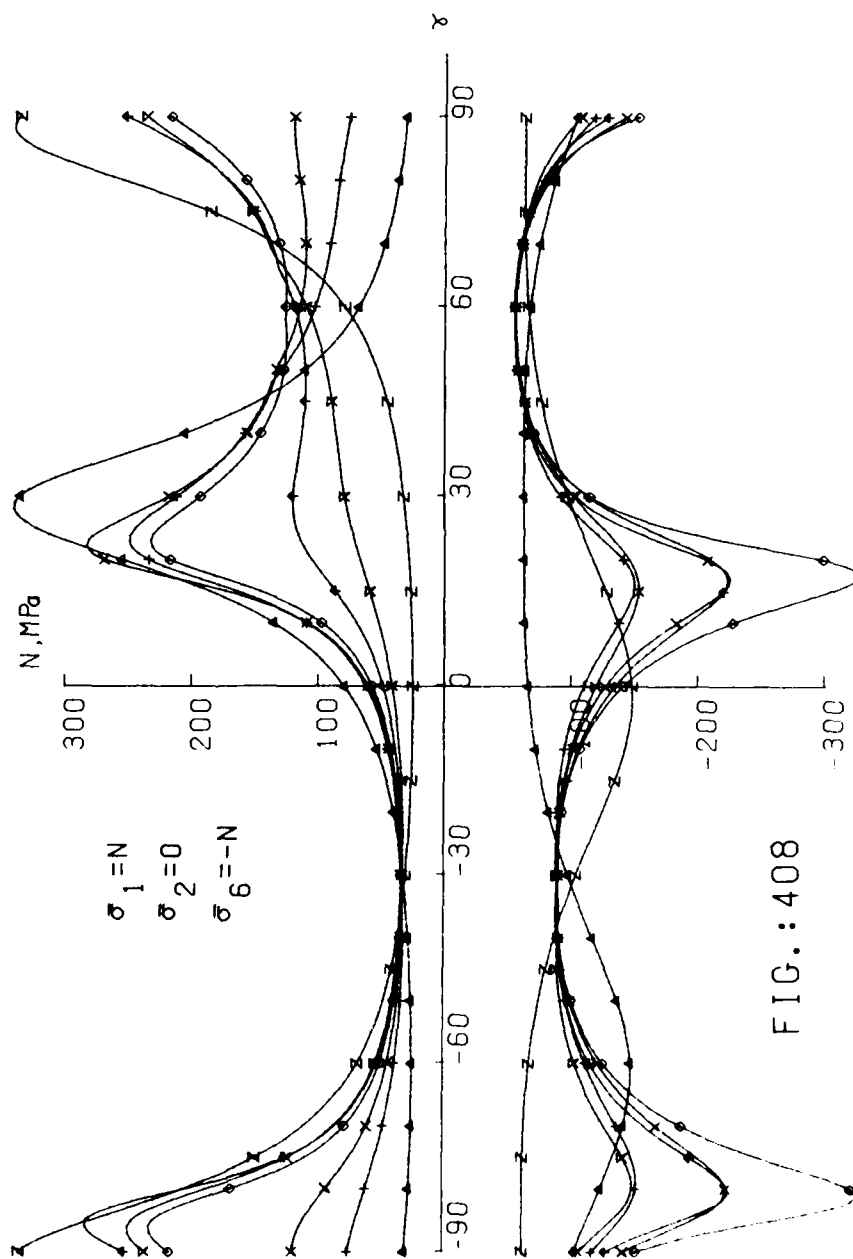
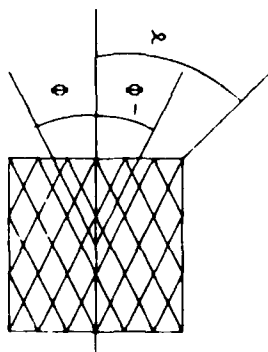


FIG.: 408



$-\phi / \phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 Φ (1/4)
 \times (1/9)
 Z (0/1)

$\Phi = 75$

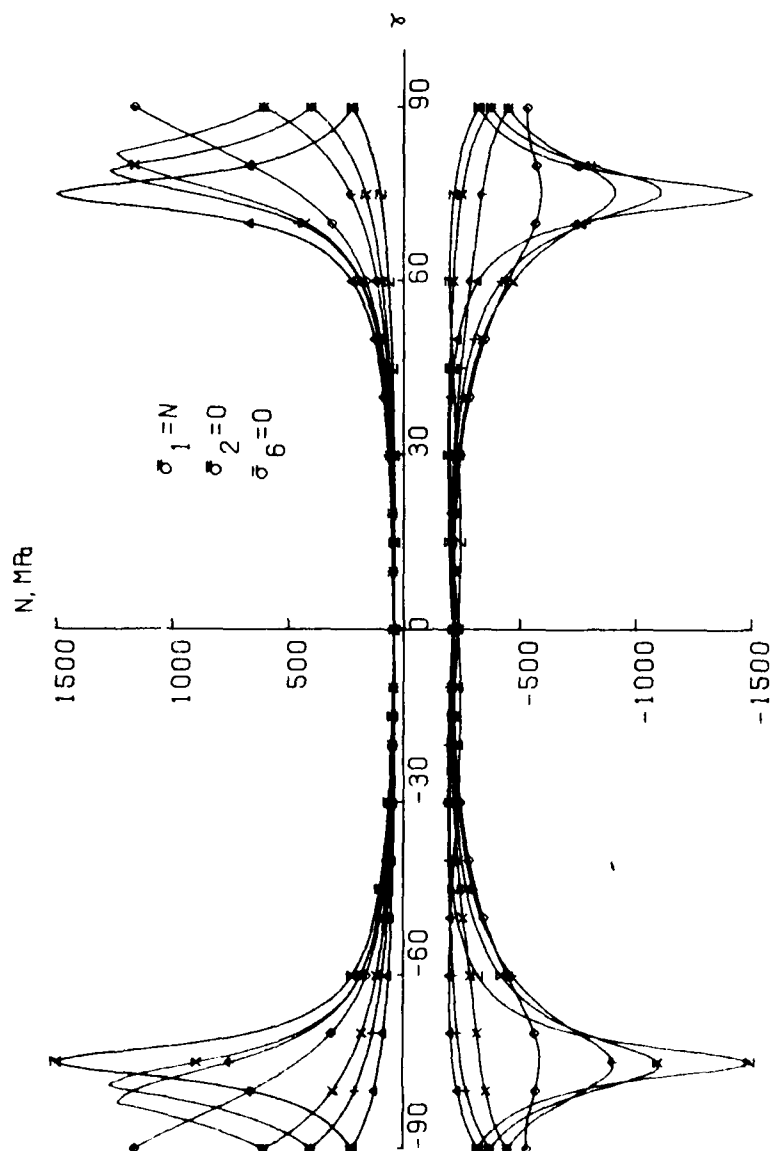
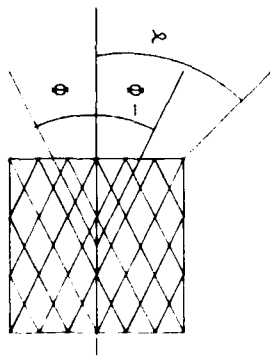


FIG.: 409



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Z (0/1)
 $\Phi = 75$

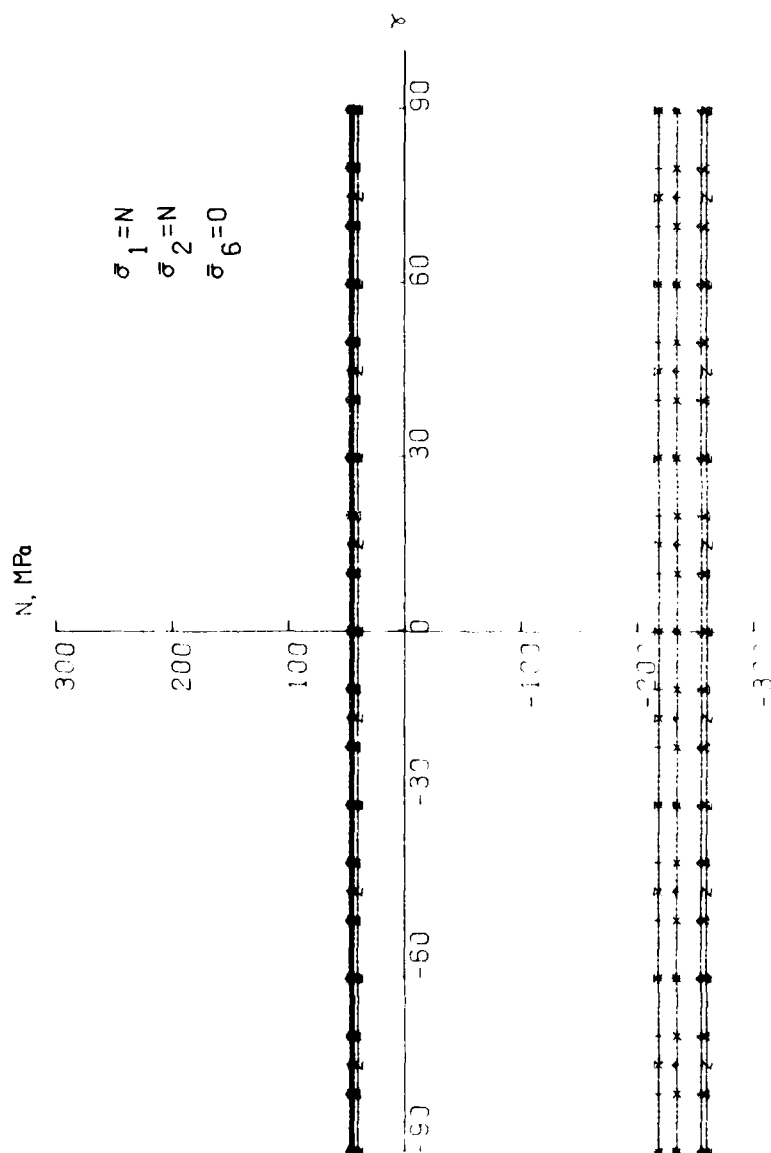
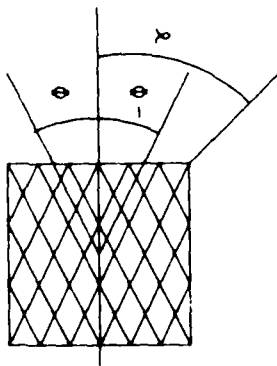


FIG.:410



$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\phi = 75$

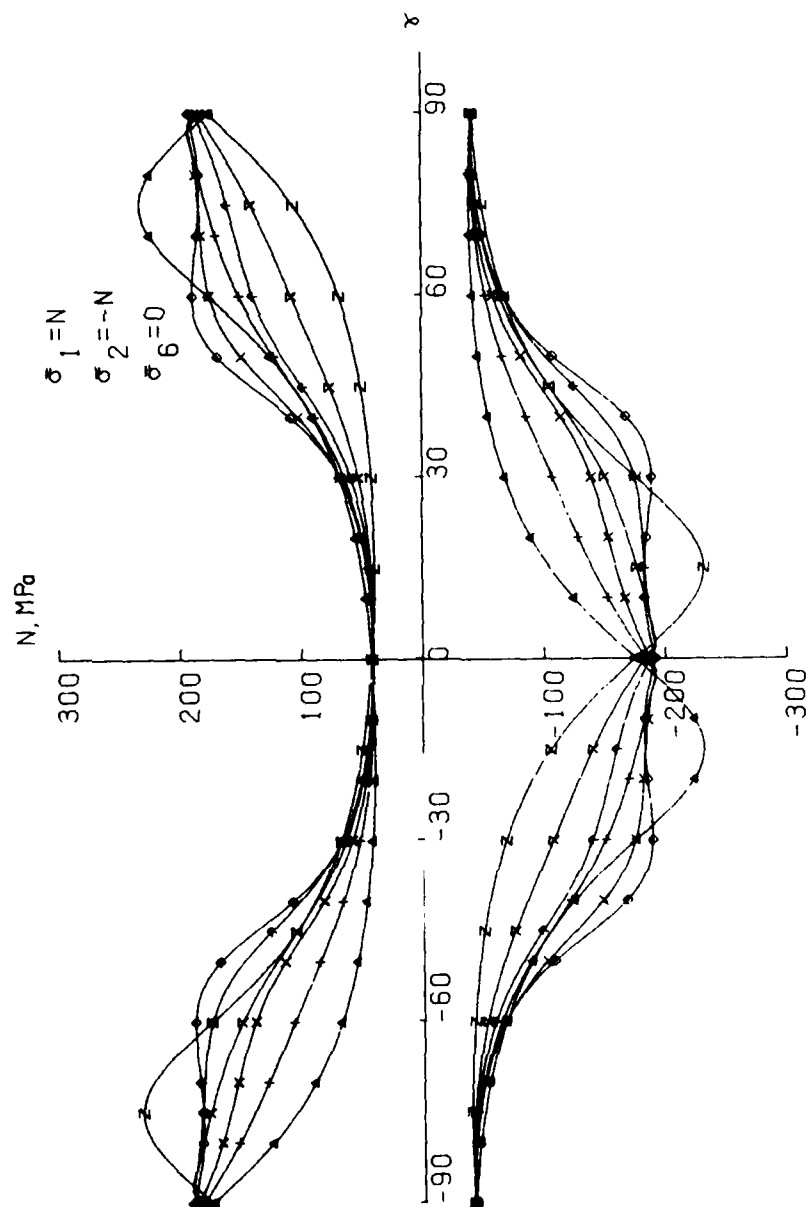
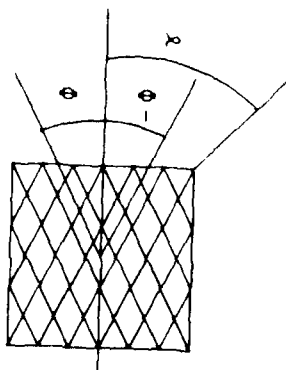


FIG.: 411



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \otimes (1/9)
 Σ (0/1)

$\Phi = 75$

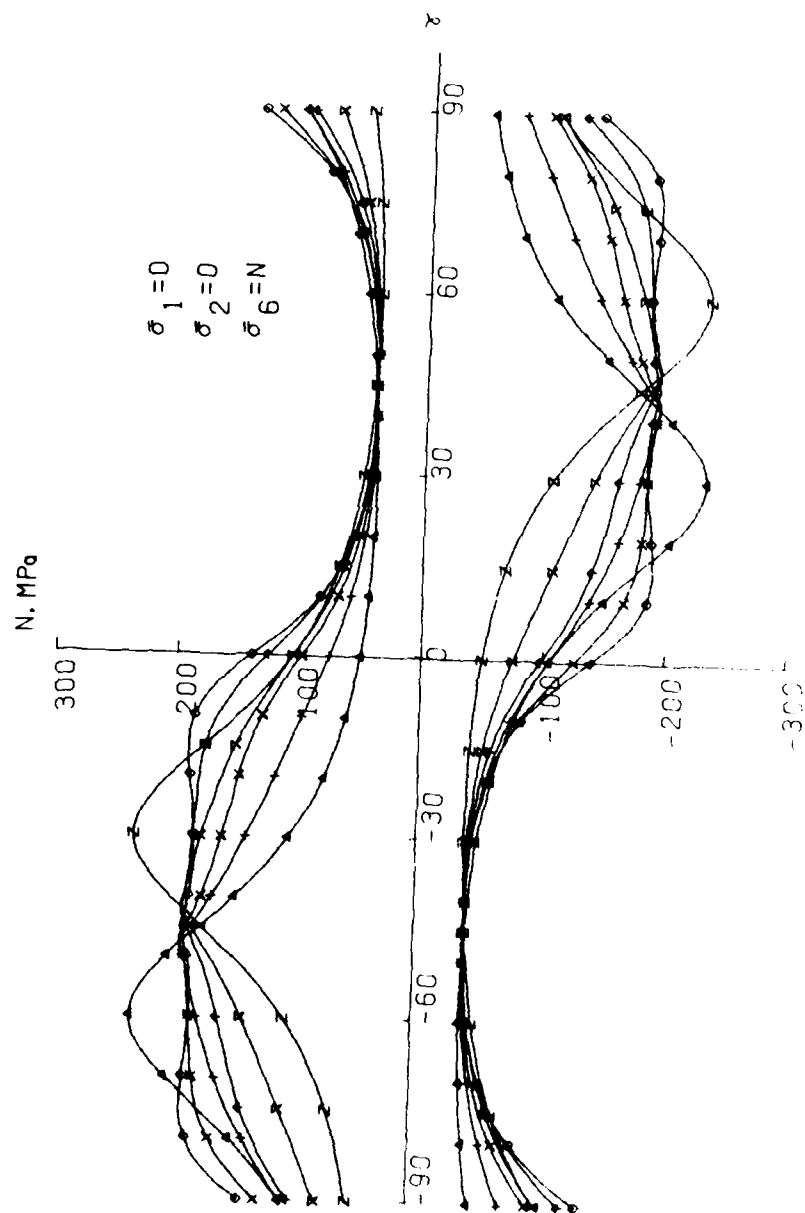


FIG.:412

$-\phi/\phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \oplus (1/4)
 \times (1/9)
 Z (0/1)

$\phi = 75$

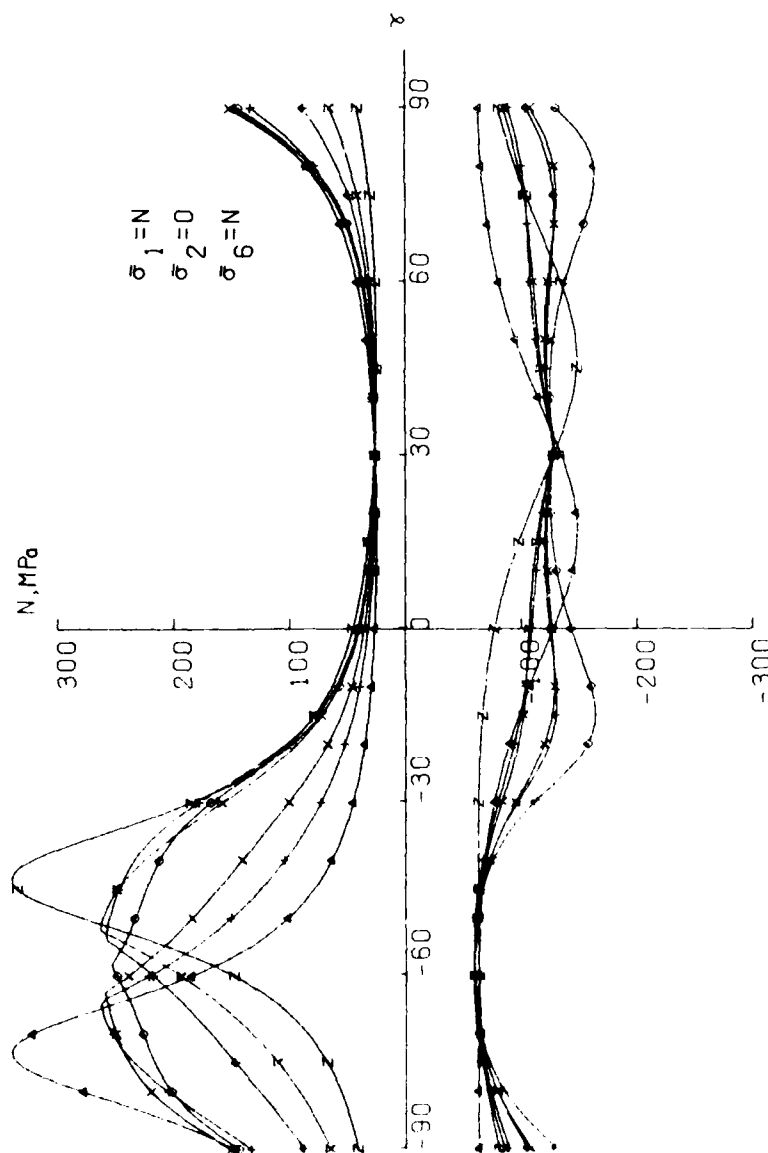
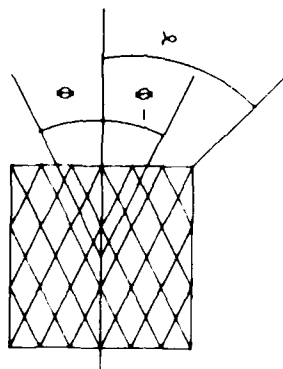


FIG.: 413



$-\Phi/\Phi$
 Δ (1/0)
 $+$ (9/1)
 \times (4/1)
 \diamond (1/1)
 \circ (1/4)
 \times (1/9)
 Σ (0/1)

$\Phi = 75$

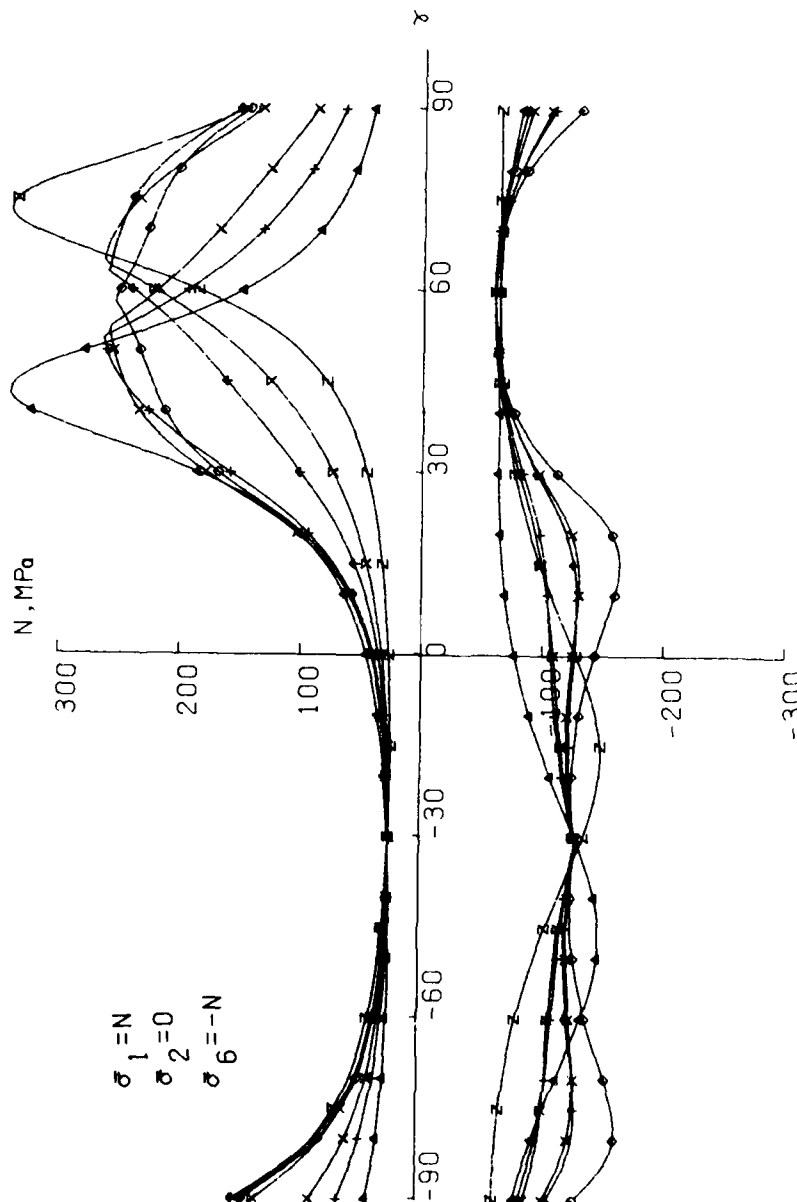


FIG.: 414